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NATURAL HISTORY SURVEY REPORTS

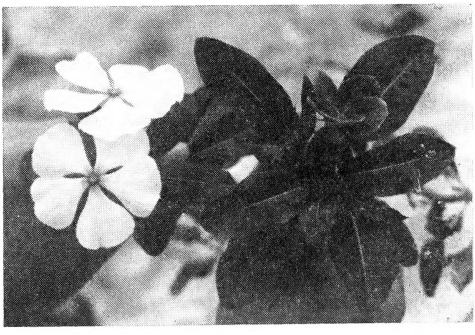
JUNE 1986, NO. 258

"The Beet Leafhopper Was Here"

Mollicutes, which include spiroplasmas and mycoplasmalike organisms (MLO), are microorganisms that resemble bacteria but do not have cell walls. Unknown prior to 1967, plant pathogenic mollicutes are now implicated in over 200 diseases of food, forage, and horticultural crops. These pathogens inhabit the phloem of plant hosts and are transmitted from plant to plant by phloem-feeding leafhoppers or by grafting. The leafhopper vectors (carriers) also serve as alternate hosts for these mollicutes. While the helical spiroplasmas can be cultured on artificial media, to date the polymorphic MLO cannot be grown outside of their plant or leafhopper hosts.

Research on horseradish (*Armoracia rusticana*) in Illinois has uncovered pathogenic mollicutes previously unknown in this crop. In 1981 researchers at the Natural History Survey and the University of Illinois, in collaboration with scientists in California and Maryland, identified *Spiroplasma citri* as the causal agent of brittle root disease of horseradish (Illinois Natural History Survey Reports 208:2-4). The beet leafhopper, *Circulifer tenellus,* was proven able to transmit this spiroplasma to horseradish. Survey entomologists Cathy Eastman and Gerald Schultz, working with University of Illinois plant pathologist Jacque Fletcher and entomologists George Oldfield and Keykavos Hemmati from the University of California at Riverside, recently reported the discovery of a second mollicute from horseradish — this time an MLO.

The MLO was found by accident during an experiment using the beet leafhopper to transmit *S. citri* from field-collected, brittle root-diseased horseradish to healthy horseradish and Madagascar periwinkle (*Catharanthus roseus*) test plants. As expected, yellowing and stunting typical of *S. citri* infection developed in four of the horseradish and two of the periwinkle test plants exposed to leafhoppers that had fed previously on brittle root-diseased horseradish. Spiroplasmas were cultured from these plants, which died within 4 months. A second set of symptoms, however, developed in other periwinkle test plants, including some from the control group of plants caged with leafhoppers fed previously on field-collected, brittle root-free horseradish. These symptoms included partial or complete virescence (greening) of the flowers, development of the flowers into leaflike structures, and shortening of internodes with bunching of leaves. Spiroplasmas could not be cultured from plants with these symptoms. In other tests using field-collected, brittle root-diseased horseradish as a pathogen source, additional



Healthy Madagascar periwinkle (left) compared with periwinkle infected with virescence agent (right) transmitted from horseradish by the beet leafhopper (photo by former Survey photographer Les Woodrum).

periwinkle test plants developed virescence. Horseradish test plants remained vegetative and, thus, could not be evaluated for virescense by symptomatology. These findings indicated that a virescence-inducing agent, transmitted by the beet leafhopper, could be found alone and in mixed infections with *S. citri* in field-grown horseradish in Illinois.

Horseradish, a perennial crucifer vegetatively propagated as an annual in Illinois, rarely flowers before harvest. However, a search of the horseradish-growing area in Madison and St. Clair counties in August, 1981, uncovered a field of an experimental line of horseradish (Illinois 984a) with a high percentage of flowering plants. Virescence symptoms were noted in 4 percent of the flowering plants examined. A small number of horseradish plants with virescence were found also in two other fields. When laboratory tests were done using the beet leafhopper to transmit the agent from some of the virescent horseradish plants, virescence symptoms developed in 11 of 20 radish (*Raphanus sativus*), 4 of 5 wild mustard (*Brassica kaber*), and 9 of 20 periwinkle test plants. All of these plants continued to grow and remained free of symptoms except for those mentioned. Some of the infected periwinkle plants are still being maintained in a greenhouse 4 years after inoculation.

Electron microscopic examinations of shoots from some of the virescent periwinkle test plants were done at the University of California at Riverside. Typical polymorphic MLO were seen in sections of phloem tissue.

The possible involvement of an MLO in the virescence condition of horseradish in Illinois is supported by the similarities of this condition with one reported in California. In 1977 Oldfield and colleagues described the transmission of a virescence-inducing agent by field-collected beet leafhoppers to Madagascar periwinkle test plants. Later reports indicated that periwinkle, broccoli, and several cruciferous weed species could be found naturally infected with virescence in southern California. MLO were found in phloem tissue from plants with these symptoms during electron microscopic examination. To date the beet leafhopper is the only known vector of the agent in California, and, as in Illinois, the virescence-inducing MLO has been found occasionally in mixed infections with *S. citri*.

The significance of the virescence condition on horseradish production in Illinois is as yet undetermined. The length of time the virescence agent has been present in the crop, the extent of crop infection, and any effects on yield are not known. While the virescence-inducing agent and *S. citri* have a common vector, the beet leafhopper, and may occur together occasionally in the same horseradish plants, these two pathogens produce distinctly different symptoms in infected plants. *S. citri* induces brittle root disease, which has destroyed as much as 80 percent of the state horseradish crop during some past epidemics. The virescence agent, however, produces no obvious adverse effects on foliage or roots of horseradish, and the effects on horseradish flowers may be of no consequence commercially in this vegetatively propagated crop. Virescence may act merely as a footprint of sorts in Illinois horseradish, indicating that "The beet leafhopper was here."

Chemical Ecology

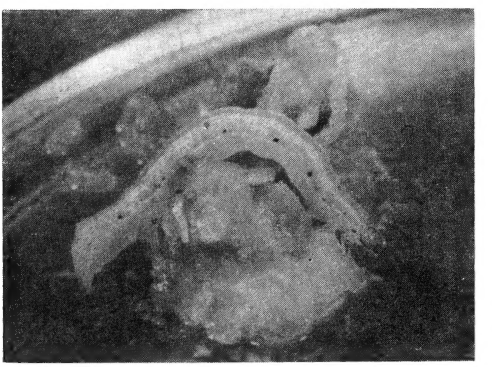
Entomologists have known since the late 1800's that plants protect themselves against insect attack by producing various chemicals that deter feeding. A vast array of chemicals has been characterized from many different plant species, and an equally impressive list of insect species affected by these chemicals has also been compiled. The rather recent discipline of Chemical Ecology provides the tools and concepts used in understanding plant chemical defenses against herbivores. Despite the boom of information on plant chemical ecology, one of the world's major crop plants, the soybean, remains poorly understood. Survey economic entomologists Alan Schroeder, Dan Fischer, and Marcos Kogan are attempting to fill this void with further research.

Plant biotechnology has been enlisted as a novel technique for studying soybean/insect chemical interactions. By culturing sterile soybean tissues in petri dishes the

Survey scientists can study the production of antiherbivore chemicals and insect responses to these tissues much more easily than can be achieved with whole plants.

To initiate these plant cultures, sterile soybean seedlings are cut into pieces which are placed on an agar-based medium that contains nutrients and plant growth hormones. Within a couple of days clumps of cells called callus begin to grow from these cuttings. Once initiated, these growing cell clumps can be cloned easily by breaking them up onto tiny pieces that will grow into large clumps when placed on fresh nutrient medium. Because of this unique cloning ability, the Survey scientists can use tissues from a single plant source and virtually eliminate the possibility of genetic variability of chemical responses within and among experiments. Another feature of these plant/insect interaction studies is the highly controllable and homogeneous conditions that are available to plant tissues that are growing in a petri dish.

The first questions that the entomologists asked were: Will insects eat this soybean callus tissue just as they eat the parent plants? And if they will, is the callus an adequate source of nutrition for insects? Using the soybean looper as their experimental animal, they set out to test this. They fed loopers on three different diets: callus derived from cotyledons (i.e., the seed leaves) of the Williams variety of soybean, intact Williams cotyledons, and nearly mature Williams trifoliolate leaves. In nature, the loopers will feed preferentially on nearly mature trifoliolate leaves and will not feed on cotyledons, if given a choice. It is thought that the cotyledon tissue is too tough for the loopers to chew through. The loopers that were fed on the intact cotyledons did not survive well and grew very poorly; whereas the loopers reared on callus initiated from cotyledons survived and grew as well as the loopers reared on nearly mature trifoliolate leaves, the preferred food. In addition, the callus and the trifoliolate leaves were nutritionally superior to the intact cotyledons. Again, the callus is seen as an adequate source of nutrients for the looper.



Soybean looper feeding on soybean callus tissue (photo by Alan Schroeder).

These results indicated that a major portion of the physical resistance afforded intact cotyledons may have been circumvented by using callus tissue. In the future, Schroeder, Fischer, and Kogan hope to see a clearer picture of the realative chemical resistance factors in various parts of soybean plants, while avoiding the variability inherent in parent plant tissues.

More recently, Williams cotyledon callus has been studied for its production of antiherbivore chemicals. By irradiating the callus with ultraviolet light, an inducer of certain soybean chemicals, the researchers, with the use of high performance liquid chromatography, were able to identify the production of a chemical called glyceollin in the irradiated callus. Glyceollin has been shown recently to be a powerful inhibitor of Mexican bean beetle feeding on soybeans.

Taking this lead, these searchers are attempting now to feed soybean callus tissues to the Mexican bean beetle. If successful, they will be able to study the effect of this chemical on the feeding behavior of the beetles. In addition, they plan to analyze the callus tissues derived from different parts of the plant and from different plant genotypes for differential production of glyceollin. If differential chemical production is found in various soybean parts and genotypes, then it should be possible, by working in collaboration with soybean geneticists, to transfer this resistance from one part of a plant to another or from one genotype to another.

Ridge Lake Closed to Fishing

Ridge Lake, a 16-acre experimental fishing lake operated by the Survey and lo-

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cated in Fox Ridge State Park, Coles County, Illinois, will be closed to fishing this year.

The lake has been drained and refilled. During this spring and summer, it will be restocked with largemouth bass, bluegill, black crappie, and channel catfish. Walleye pike and additional catfish will be stocked in 1987, 1988, 1989. Fishing will not be permitted until 1987 so that fishing populations will have time to attain densities necessary for good fishing.

The most recent study conducted at Ridge Lake was on the tiger muskellunge (*INHS Reports,* No. 254). The tiger muskellunge, which is the hybrid of the muskellunge and the northern pike was introduced to the lake with the idea of improving the balance between predator and panfish populations. It was found that the tiger muskellunge can make a useful contribution to the sport fishery of small, warmwater impoundments dominated by bass and bluegill.

The project on the tiger muskie at Ridge Lake was a cooperative project; funding for the study was provided by the Illinois Department of Conservation and the U.S. Federal Fish and Wildlife Service as Federal Aid Project F-40-R.

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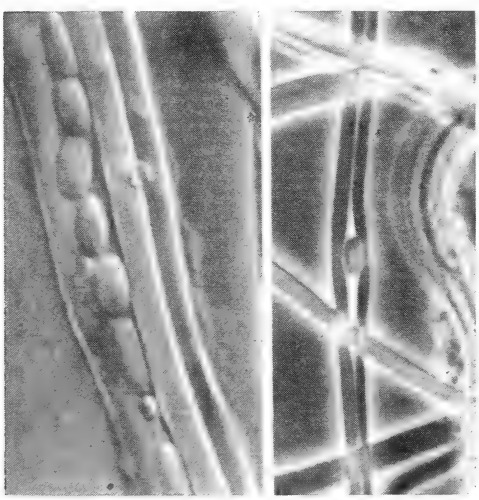
The Illinois
NATURAL HISTORY SURVEY
REPORTS

SEPTEMBER 1986, NO. 259

Promising New Pathogens of the Gypsy Moth

When the gypsy moth was accidently introduced from Eurasia into North America in 1869, its natural control agents (parasites, predators, and pathogens) were left behind. As a result, millions of forested acres have been defoliated over the last 100 years. Today, the gypsy moth continues to be a serious forest pest.

During the last 80 years, scientists have attempted to import and establish natural controls to reduce the magnitude and duration of gypsy moth outbreaks. Most of the attention has focused on parasites. To date, 11 species of parasitic flies and wasps and one species of predatory beetle have been established to combat the gypsy moth in the United States. Pathogens, however, have been severely neglected. Only one European pathogen, a nuclear polyhedrosis virus, has been established in North America as a permanent biological control agent. While this disease ultimately causes large gypsy moth populations to crash, these epizootics, or wide-range spreadings of disease, do not occur until after extensive defoliation has already occurred.



Spores embedded within an individual gypsy moth silk strand, and a spore enclosed within a double strand of silk. Spores are about 5 microns in length (photo by Michael Jeffords).

One group of important insect pathogens, the microsporidia, is found to commonly infect the gypsy moth and is reported to be an important mortality factor in Eurasian gypsy moth populations. Surprisingly, no previous attempts have been made to introduce these gypsy moth pathogens into North America.

Under a cooperative agreement with the US Forest Service and with the support of the Illinois Department of Energy and Natural Resources, Survey entomologists, J. V. Maddox and M. R. Jeffords, travelled to Portugal, Yugoslavia, and Czechoslovakia during the spring of 1985 to collect gypsy moth microsporidia. Eleven microsporidian isolates, representing at least five different species, were obtained. Six species of microsporidia had been previously identified from Eurasian gypsy moths and additional reports suggested that several undescribed species also occur. The unknown microsporidian isolates obtained from Europe are being characterized to determine: (1) the species represented by the isolates, and (2) their infection characteristics in the gypsy moth.

To introduce any microsporidian into gypsy moth populations, certain relationships between host and pathogen must be

understood. For a microsporidian to be a significant factor in reducing gypsy moth populations, it must persist in the population throughout the season and from year to year. Two main factors that affect the ability to persist are horizontal and vertical transmission efficiency. Horizontal transmission is the spread of the disease organism from individual to individual within the same generation. In microsporidia, horizontal transmission occurs by the ingestion of resistant spores by a healthy gypsy moth larva. Spores are released into the external environment from infected larvae in a number of ways. In the microsporidian genus *Pleistophora,* incredibly large numbers of spores are released in the feces and from the decay of infected larvae that die. In the genus *Nosema,* spores are also passed with the feces; however, spores also have been found in and on the silk produced by gypsy moth larvae. This is an important discovery since gypsy moth larvae follow silk trails between feeding and resting sites. Therefore, the presence of spores in silk is a potentially important, as well as efficient, means of horizontal transmission. Vertical transmission is the passage of the disease from one generation to the next via infected females. Females may either lay eggs infected with microsporidia, or they may contaminate the eggs' surfaces with spores at oviposition.

In addition to the laboratory studies on microsporidia, Survey scientists, in cooperation with the US Forest Service and the USDA Agricultural Research Service, have initiated a field-release program to test methods of introducing microsporidia into gypsy moth populations. The study also monitors horizontal and vertical transmission efficiency. Two species of microsporidia were released in Maryland in 1986 by coating laboratory-reared gypsy moth egg masses with spores and introducing them into isolated, gypsy moth infested woodlots. Results of season-long sampling showed that both species of microsporidia persisted in the environment and spread in gypsy moth populations. Infected larvae were found as far as 25 meters from the introduction site. Many of the larvae dissected showed low-level infections which indicate that horizontal transmission had occurred during the season. The experimental release sites will be closely monitored for the next few years to determine the impact these pathogens have on gypsy moth population levels. New field sites will be established as other microsporidia are properly identified and found to demonstrate the desired characteristics necessary for persistence and spread in wild gypsy moth populations.

By *Michael Jeffords*
Section of Economic Entomology

Phil Smith Honored

Dr. Philip W. Smith, former head of the Faunistic Surveys and Insect Identification Section at the Survey, was given an honorary Doctor of Science degree at the summer commencement ceremonies at Eastern Illinois University August 10.

Dr. Smith, who is an internationally known zoologist, was at the Survey for 33 years. He was named head of the section in 1969 and retained that position until he retired in 1979. He held a dual appointment, also teaching zoology at the University of Illinois from 1969 to 1979.

Although he received his bachelor's degree at the University of Illinois, he attended Eastern from 1940-1942 and during 1946-1947. He holds a master's degree and a doctorate from Illinois.

Two of Dr. Smith's three books have been recognized as definitive works in their areas: *The Amphibians and Reptiles of Illinois* (first published in 1961 and now in its fifth printing) and *Fishes of Illinois* (published in 1979). The most recent book is *A Naturalist in the Environmental Crisis,* which covers most of his life as a zoologist and is written in the non-technical style particularly interesting to the lay person.

In addition to the books, he has published more than 100 papers and belongs to many professional societies. He has served on the Board of Governors of the American Society of Icthyologists and Herpetologists, was editor of its journal, and was the Society's vice president in 1966.

By *Shirley McClellan*
Administrative Unit

The Illinois Natural Resources Information System (INRIS)

In recent years, the increasing speed, affordability, and availability of large computer and communications systems has enabled much greater data access than previously. The Natural History Survey has taken an active part in the automation of various natural resources and environmental data sets, bibliographies, zoological collections, simulation models, reports, and other information. Our two sister Surveys, the Geological Survey and the Water Survey, also have many such "products," as do several organizations either affiliated with the Department of Energy and Natural Resources or having similar missions. Recently all three Surveys agreed to participate in the contribution of these products to the Illinois Natural Resources Information System (INRIS), so that many persons can have the benefit of cooperative access to a large part of the natural resources data of Illinois. INRIS is designed to enable selected users within the DENR; other agencies; educational institutions; local, state, and federal governments; businesses; and the public to access this information. In addition to making selected information available to the public, INRIS should help foster a public understanding of the type of work performed by the Surveys.

Located on a large Prime minicomputer, INRIS is a framework through which users may access individual products via terminals directly connected to the Prime, or via modems connected to either terminals or personal computers (PCs). (A modem is a device which transmits data over phone or other communication lines, between different computers.) Access to sensitive information may be restricted to certain agencies or groups of individuals. All products, of course, remain the property of the contributing individual or agency, and appropriate credit is given to contributors. The INRIS Director, Mark McReynolds, and others are available to assist contributors in establishing their products on INRIS, including writing applications programs to facilitate access of products by INRIS, and developing accounting programs to quantify use of their product.

An INRIS user can choose a particular product from a series of menus, simply by typing the number corresponding to that menu choice. Alternatively, commands which directly access each product are available. If the product chosen is a simulation model it prompts the user for the required data. If a user is missing certain data items, some models can provide him with "default" data values, which are the model developer's best approximations of average values for each data item. The user can choose to view output on his terminal or PC screen, transfer it into a file on his PC (or with users having logins on the Prime, redirect it to another Prime file external to INRIS), print it at his PC printer, or have it printed at the Survey line printer.

The INRIS staff will be continuing to add more products. Current products include several agricultural news items from Illinois and national sources, updated daily or biweekly. These include news about agribusiness, changes in federal agricultural programs, applications of agricultural research, care of livestock, pesticide and herbicide information, tillage practices, etc. In addition, the Emergency Pest Reports, the Cereal Rust Bulletins and other messages from US Department of Agriculture APHIS (the Animal and Plant Health Inspection Service) are available and are regularly updated. A few agricultural and entomological simulation models are available, including models projecting the soybean defoliating pest population level at which it becomes economically advantageous to apply pesticides, and the predicted crop damage in various regions of Illinois due to black cutworm infestation. In addition, selected Illinois weather data and forecasts are available. A data base of Illinois soil type data from the Soil Conservation Service is available, which contains several geological and agricultural parameters for each Illinois soil type.

INRIS also contains an on-line version of the *Illinois Directory of Systematists and Ecologists,* compiled by Survey personnel, whereby experts in various fields of ecology and taxonomy can be located. A large bibliographic data base concerning United States bird publications is avail-

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able. This gives the user the ability to search by a publication's title, subject, date, author's name or field of expertise, a number of keywords in the publications, and other parameters. Other faunistic bibliographies written in the same data base format are planned as later products. Also, the Geographic Names Information System will soon be available, which will enable users to access several types of data concerning Illinois place names.

Although several of the ideas upon which INRIS is based have been contributed by a number of persons, the current version of the system was developed primarily by Annette Holloway and managed by Ed Armbrust. Those who would like to use or to contribute data to INRIS are encouraged to contact Mark McReynolds, INRIS Director, at (217) 333-6006, or by mail at 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

By *Mark McReynolds*
Section of Economic Entomology

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The Illinois
NATURAL HISTORY
SURVEY REPORTS

OCTOBER 1986, NO. 260

Seasonal Dynamics in Small Wetland Pools

More than a century ago, just as engineers were beginning to impose controls on our major streams, ecologists at the Illinois Natural History Survey recognized the importance of floodplain lakes as critical habitats for fish and wildlife. In 1877, Stephen A Forbes, first Chief of the Survey, vividly described the seasonal dynamics of floodplain pools; how the floodwater filled the low areas of the floodplain, captured nutrients for the production of plankton, benthos, and fish; and carried some of these products back to support river communities.

In spite of this early awareness of the value of these waters, many floodplains have been isolated from the river with levees and drained for agriculture. Farmers formed drainage districts and, through tiles and ditches, lowered the water table behind the levees. Not only were floodplains lost for the storage of flood waters and as fish and wildlife habitats, but water drained rapidly from the land, most of which had been put to row crops, moving soils downstream to be deposited in the quiet backwaters of the lowland rivers.

In an intensive investigation of the seasonal dynamics of these systems, R. Weldon Larimore and his associates studied the physical and chemical conditions and biological communities in small floodplain pools and in the adjacent Kaskaskia River of central Illinois. The greatest influence on the seasonal dynamics of these pool systems was the extent of thermal and

Two researchers investigate Kaskaskia floodplain pool for spawning fish and aquatic vegetation (photo by W. D. Zehr).

chemical stratification, related to isolation from the river and winds. In isolated pools, fish, plankton, and benthic populations were severely limited by surface mats of algae, dense stands of aquatic vegetation, accumulation of detritus, oxygen exhaustion, and flocculent bottom materials. During periods of flushing, many fish moved into the floodplain pools to spawn and the young produced there took advantage of the generally abundant spring zooplankton. But isolation of the pools prevented this production of fish and fish foods from contributing to the river communities.

Levees and drainage ditches have eliminated a high percentage of the floodplain waters of the Mississippi basin. Many of the remaining pools are dying as a result of an increased rate of sedimentation from more turbid waters and because of isolation from the river. Various degrees of isolation may reduce or eliminate seasonal flushing of detrital accumulations and restrict the passage of organisms both in and out of the pools. Isolation, if accompanied by dense stands of forest growth, speeds eutrophication by contributing excess amounts of detritus (leaf fall), reducing sunlight for photosynthesis, and inhibiting water mixing caused by exposure to surface winds. Although winds will increase turbidity in open expanses of shallow lakes, the gentle mixing may stimulate decomposition of accumulated organic materials.

Some suggested management potentials for these natural waters are to (1) improve the connections to river floodwaters in old floodplain pools; this might involve reestablishing former connections in newly created oxbow lakes, such as are created in channel improvement projects; (2) maintain year-around minimum depths (with an occasional dry season to encourage oxidation of organic deposits); and (3) reduce surrounding woody plants to decrease the excess detrital input and to increase exposure to mixing winds.

By *R. Weldon Larimore*
Aquatic Biology Section

IN MEMORIAM
PHILIP WAYNE SMITH

Dr. Phil Smith died early Saturday morning, October 11, 1986, at Mercy Hospital. He had been ill for many months. Memorial services were conducted at the Mittendorf Funeral Chapel, Sunday, October 19.

"Except for a 37-month tour of military duty during World War II, Mr. Smith worked for the Illinois Natural History Survey from 1942 until his retirement in 1979. In his last 10½ years with the Survey, he was head of the section of faunistics and insect identification.

"His research was primarily on the systematics and ecology of fishes, amphibians, and reptiles. He was the author of three books and more than 100 journal articles.

"Mr. Smith also held the titular appointment of professor of zoology at the University of Illinois graduate school for 14 years.

"He attended Eastern Illinois University from 1940 to 1942 and from 1946 to 1947. He did graduate work at the University of Illinois and earned his doctorate in 1953. He was awarded the honorary degree of doctor of science by Eastern in August.

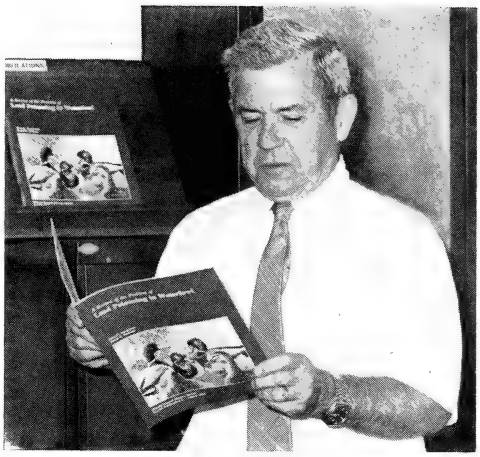
"Mr. Smith held several offices and served on governing boards and committees in a number of international, national, and regional scientific societies. Most of those organizations pertained to his interest in systematics and evolution of fishes, amphibians, and reptiles.

"Among non-scientific organizations, he held offices in the local Antiques Study Group, the East Central Illinois Doll Club and the Champaign-Urbana Pistol Club. He was a member of the Wabash Valley Gun Collectors Association and several Bing Crosby fan clubs."

On learning of Dr. Smith's death, Acting Chief Larry Pace remarked, "Those of

us who knew Phil will miss him very much but also will remain forever grateful that he chose to contribute so substantially to the scientific tradition upon which the future of the Illinois Natural History Survey depends."

The obituary part of this article was written by Dr. Smith.



Glen Sanderson examines new publication (photo by Molly Hardin). The picture of the ducks on the publication was taken from an oil painting by Beverly Sanderson.

Lead Poisoning in Waterfowl

Drs. Glen C. Sanderson, Head of the Section of Wildlife Research, and Frank C. Bellrose, waterfowl biologist for more than 48 years, with the Natural History Survey, have written a report "A Review of the Problem of Lead Poisoning in Waterfowl," which has been published as the Survey's Special Publication 4.

Publication comes at an appropriate time. In 1985 and 1986 the National Wildlife Federation sued the US Fish and Wildlife Service in Federal Court in an attempt to force the use of steel shot for waterfowl hunting at an accelerated rate in order to protect waterfowl from lead poisoning. Another purpose was to protect the endangered bald eagle from secondary lead poisoning contracted from feeding on crippled and dead waterfowl and ingesting lead pellets in the process. Partly as a result of the lawsuits, the US Fish and Wildlife Service has announced a phasing-in process for the 100 percent use of steel shot for hunting waterfowl by the 1991-1992 hunting season. Although most biologists support the use of steel shot for waterfowl hunting, some organized groups of waterfowl hunters are strongly opposed to its use. Thus, the use of steel shot remains controversial in many states, including Illinois.

Sanderson and Bellrose explain their purposes in preparing this report:

"Because professionals and the general public have been inadequately informed about the problem of lead poisoning in waterfowl and because of misconceptions about the effectiveness of steel shot, we have undertaken a comprehensive review of these subjects. Our purposes are three: (1) to provide an up-to-date summary of the effects of lead poisoning in waterfowl, (2) to summarize and briefly discuss the main issues that have led to differences of opinion regarding the magnitude of the problem, and (3) to review the differences to be found from the use of steel rather than lead shot. We have prepared this report with the expectation that biologists, wildlife managers and administrators, legislators, the general public, and especially waterfowl hunters will find the information helpful in understanding an extremely complex problem."

Waterfowl die from ingesting lead shotgun pellets deposited in lakes, marshes, and fields. Because of the widespread distribution of lead shot from the breeding grounds to the wintering grounds, it is available fall through spring to waterfowl feeding on areas that have been hunted. As a result, mortality happens on a day-to-day basis. These losses, however, are often overlooked because predators quickly dispose of sick and dead birds. Studies in Missouri and Texas, for example, showed that predators rapidly removed waterfowl carcasses placed by biologists in wetland habitats. Also, dead ducks in natural settings are difficult to find, and freshly planted carcasses in marsh vegetation were largely overlooked by searchers employed to find them. Most die-offs from lead poisoning occur after the hunting season, when few hunters are where the ducks are dying. Only when massive die-offs of waterfowl occur in a limited area do losses from lead poisoning attract public notice.

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The potential impact of lead poisoning on waterfowl has been determined from many sources. Almost 200,000 gizzards from more than 16 species of waterfowl from many regions have been examined for lead shot. Scores of experiments with penned wild and game-farm waterfowl have been conducted by numerous researchers to evaluate the effects of shot dose, nutrition, age, and sex.

Species of waterfowl vary in their ingestion of shot and, because of differing food habits, in their susceptibility to ingested lead. Lead poisoning poses the greatest threat to mallards, followed in lessening degrees by black ducks, mottled ducks, pintails, canvasbacks, redheads, and ring-necked ducks. The potential for lead poisoning in other duck species is low. At times swans and geese die in numbers sufficiently large to cause concern.

Steel shot as a substitute for lead shot in waterfowl hunting is the only currently feasible solution to the problem of lead poisoning. Steel shot is less dense than lead shot but produces a tighter pattern and shorter shot string. The lower density of steel can be compensated for by increasing shot size and velocity. No significant differences in crippling rates were found in all but 3 of 15 tests comparing the effects of steel and lead shot. Crippling losses to waterfowl populations from steel shot are less harmful than crippling losses plus lead poisoning from lead shot. Several related points merit consideration: lead poisoning causes important losses to the most abundant species of waterfowl. The sublethal effects of lead poisoning are recognized but have not been quantified. Except for a brief period in spring, lead may affect females more adversely than males. Seasonal differences in the time of losses are important. A cripple lost during the hunting season has less impact on the breeding population than a lead-poisoned duck lost during the winter or spring.

Single copies of the published report are available from the Chief of the Illinois Natural History Survey.

By *Glen Sanderson,*
Head, Wildlife
Research Section

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Illinois
NATURAL HISTORY SURVEY REPORTS

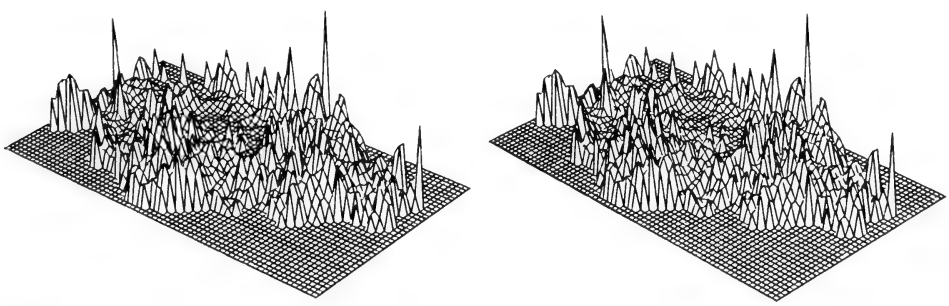
NOVEMBER 1986, NO. 26

Woody Biomass Maps Show Renewable Energy Potential

Following a century of steady decline, the use of wood for residential fuel doubled between 1972 and the early 1980's. Nationwide, almost 10 percent of the energy used in homes now comes from wood, and in Illinois, about 25 percent of households burn some firewood. Industry is greatly increasing its use of wood energy by taking advantage of inexpensive sources of fuelwood such as logging residues and wastes from wood processing mills. Together, all forms of "woody biomass" could supply more than 20 percent of the energy demand in the United States without depleting our forests.

In addition to its renewable nature, wood has many advantages as a fuel. Controlling pollution from wood-fired power plants is relatively simple and inexpensive. A mixture of wood and coal may prove to be a promising fuel for utilities as research in Europe has shown that wood ash absorbs troublesome sulfur emitted by coal. Through its effects on wildlife habitat and soil erosion, the production of fuelwood also has important benefits. If the economic and environmental benefits of wood energy are to be used to best advantage in Illinois, however, we need to know more about the state's existing woody biomass resources, and develop better woodland management methods. Research is being conducted by Survey ecologist Christopher Burnett on the first problem. Progress on the second problem of developing better woodland management methods will appear in subsequent issues of *INHS Reports*. These investigations are part of a larger study of Illinois' renewable energy resources being sponsored by the Illinois Department of Energy and Natural Resources.

In 1985, the US Forest Service conducted the first detailed inventory of Illinois' timber resources to include estimates of the total amount of woody biomass, not just the merchantable logs. First, aerial photos were interpreted to classify the type of vegetation occurring at about 187,000 points across the state. Then, detailed ground cruises were conducted on a subset of these points to develop biomass yield tables for each woodland type that could be recognized in the aerial photos. By combining these two types of information,



Fishnet map of total existing woody biomass in Illinois. A pocket stereoscope can be used to see the map in 3-D (computer-plotted maps by Christopher Burnett).

the Forest Service is producing statistical reports on Illinois' woody biomass resource.

The objective of the Survey's study, however, was to produce maps showing the geographic distribution of woody biomass in the state so that interested persons can obtain a broad overview of the resource without consulting massive tables. Rather than attempting to map 187,000 points, average values were calculated for 36-square-mile blocks, resulting in 1,683 map units statewide. Various types of maps were then produced via the Survey's computerized geographic information system.

The maps shown in the accompanying illustration are known as block diagrams or fishnet maps. In this type of map, the higher the surface of the state appears, the more woody biomass there is at that location. The two maps are of the same data, but are shown from slightly different angles. By using a pocket stereoscope of the type used to view aerial photos, one can obtain a dramatic 3-D image of the state's woody biomass resource. In general, the highest levels of woody biomass occur in the southern and west-central parts of the state, although significant peaks occur in other areas as well.

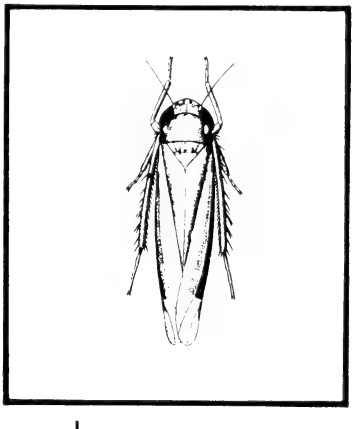
By *Christopher Burnett*
Wildlife Research Section

Alfalfa, Insects, and Weeds

The potato leafhopper is the most important pest of alfalfa during the second, third, and sometimes fourth regrowth in Illinois. Each year it migrates north from overwintering sites in the Gulf states. The few individuals that arrive here rapidly reproduce and soon damaging numbers of this pest appear. Currently there are only two major control tactics: use of insecticides and early harvesting, when feasible.

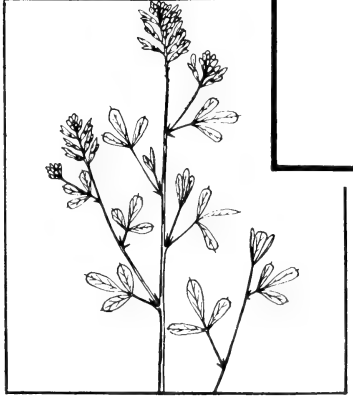
Researchers, led by E. J. Armbrust at the Natural History Survey, have been engaged in the study of interactions among alfalfa, insect pests, and weeds in alfalfa and found that weed grasses are repellent to the potato leafhopper. The next question was whether or not grasses could be used to help control the ravages of this pest.

Choice tests were used to determine which sense potato leafhoppers use to detect grass: vision, smell, taste, or touch. For a choice test, leafhoppers were placed in a rectangular cage. Alfalfa was always placed at one end of the cage as a control, while test plants were placed at the other end. After 6 days, leafhoppers and eggs in the alfalfa at each end of the cage were counted. A preliminary test demonstrated that grass does repel the potato leafhopper. Sixty percent of the leafhoppers and eggs



Potato Leafhopper

Alfalfa



Original drawings from Special Publication 51, College of Agriculture, University of Illinois

were consistently found on alfalfa at the control end of the cage rather than at the end with an equal amount of alfalfa and grass.

In another experiment, alfalfa was again placed at both ends of the cage, but this time grass was placed outside the cage at the test end. The leafhoppers in the cage might still see and smell the grass through the thin screening of the cage, but were not allowed to touch or taste it. When counts were made, more leafhoppers and eggs were found at the control end of the cage. These results exclude taste or smell in perceiving grass. The next experiment was set up just as the last, except that instead of grass, alfalfa that had been dipped in grass macerate was placed outside the test end of the cage. Now the leafhoppers could only smell and no longer see the grass. Again similar results were obtained; more leafhoppers and eggs were found at the control end of the cage, away from the alfalfa with grass macerate. This set of three experiments shows clearly that the sense of smell is most used by potato leafhoppers to perceive grass.

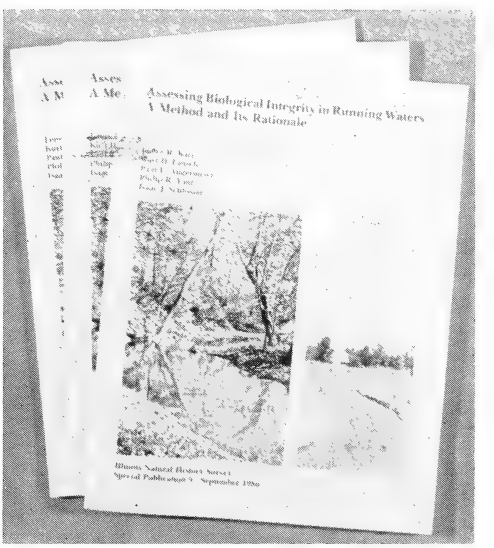
In order to study which behaviors grass affected, potato leafhoppers were put into cages with grass and alfalfa with ratios of grass to alfalfa ranging from 0:1 to 4:1. The leafhoppers in each cage were observed daily, and at the end of 6 days the leafhoppers were dissected to count developing eggs, plus plants were dissected and the eggs laid were counted. Observations showed flights per minute and numbers of leafhoppers resting on sides of the cage, rather than on the alfalfa, increased with increasing ratios of grass to alfalfa. At ratios higher than 1:1, there were no further increases. This suggests that grass causes increased activity and restlessness. When eggs laid and developing eggs in dissected females were counted, however, fewer eggs were found as the ratio of grass to alfalfa increased. The reduction in number of developing eggs in females ranged up to 60 percent at a ratio of grass to alfalfa of 1:1 compared to the control cage with alfalfa only. It seems the reduction in the number of eggs was due to the diversion of energy and time to greater flight activity in addition to less time spent eating.

Current and future research will concentrate on the economic feasibility of using the presence of weed grasses or mixed stands of pasture grass and alfalfa as a means of reducing yield loss caused by the potato leafhopper.

By *Lane Smith*
Section of Economic Entomology

Assessing Biological Integrity in Running Waters

Special Publication 5 of the Illinois Natural History Survey, *Assessing Biological Integrity in Running Waters: A Method and Its Rationale,* describes a system of using biological rather than chemical and physical water quality to measure the biotic integrity of streams. The authors,



Cover of Survey Special Publication 5 (photo by Molly Hardin Scott).

James R. Karr, Kurt D. Fausch, Paul L. Angemeier, Philip R. Yant, and Isaac J. Schlosser, write "a major purpose of this document is to argue that ecologists, aquatic biologists, and ichthyologists must assume major roles in monitoring, evaluating, and managing our water resources. This paper, therefore, demonstrates the need for a method to assess biotic integrity directly, provides a conceptual framework for biological monitoring, and describes a

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useful tool for biological monitoring — the Index of Biotic Integrity."

Measures of physical and chemical water quality have dominated the efforts to restore the integrity of water resources. The presumption was that improvements in biological quality would follow improvements in chemical and physical qualities. Although this approach provides a certain statistical validity and legal defensibility, it does not measure biological or ecological conditions. Thus, it is not surprising that the biotic integrity of water resources has continued to decline. A recognition that certain kinds of variability are natural has encouraged a closer look at human-induced alterations, but the emphasis has stayed with chemical monitoring, mostly the quality of effluent of point sources. Point-source permits and concentrations of toxic chemicals continue to dominate regulations and many factors that degrade waters are overlooked, whether they are natural or human induced.

As tools are being developed to measure biotic integrity of waters, they have been criticized because they do not work equally well in all cases, are too expensive, too time consuming, and are subject to gear selectivity. The Index of Biotic Integrity (IBI) was designed to take advantage of a range of factors in assemblages of fishes. It has 12 measures organized in three categories: Species Composition, Trophic Composition, and Fish Abundance and Condition. Data are collected for each factor at given sites and compared with what might be found at natural sites in a similar region and on a stream of similar size. A numerical rating is assigned to each factor and the sum of 12 ratings gives a score for the site being evaluated. "The strength of IBI is its ability to integrate information from individual, population, community, zoogeographic, and ecosystem levels into a single ecologically based index of the quality of a water resource."

The authors caution that the concepts from which IBI was developed are important, but the details must be tailored to fit the geographic region in which the index is used.

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By *Glen C. Sanderson,*
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Endangered Prairie-Chickens and Some Species Interactions

Illinois' prairie-chickens comprise the last remnants of once-legendary abundance on native range east of the Mississippi River. Two populations numbering about 200 birds in spring 1986 are supported by two sanctuary systems totaling 1,960 acres in Jasper and Marion counties. The 14 scattered sanctuaries in the two systems are owned or leased by The Nature Conservancy (TNC) and the Illinois Department of Conservation (IDOC), and are cooperatively managed by TNC, IDOC, and the Illinois Natural History Survey (INHS).

Spring display and courtship by male prairie-chickens on their traditional booming grounds are well-known and popular spectacles, typically attracting hundreds of visitors. Less well-known, but also common, is territorial display (but not courtship) in autumn. Censuses conducted on the main study area near Newton in Jasper County by Survey wildlife ecologist R. L. Westemeier and his associates over the past 21 years have shown that peak numbers of displaying males occur in late October or November, whereas the peak in spring occurs in early April.

The fall count has been highly predictive of the subsequent count in spring. Autumn counts have been within 75-99 percent (average of 92 percent) of counts for the subsequent springs in 18 of 20 comparisons. Two spring counts, 1972 and 1986, were 33 percent and 45 percent higher, respectively, than censuses made the preceding falls. In 1972, prior to the intervention of pheasants, nearly 400 prairie-chickens comprised the population on the Jasper County area, and these were spread over 13 booming grounds and 8 square miles. Thus in 1972, the difficult logistics of censusing a large, widely distributed population precluded an adequate fall census. In contrast, by 1985–1986, with a greatly reduced population (owing largely to pheasant interference) of approximately 70 prairie-chickens using only three booming grounds in three sections, censusing should have been relatively simple. However, a difference of 45 percent between the peak count of 29 males in fall 1985 and 42 males in spring 1986 resulted from an unusually large influx of wintering harriers and short-eared owls. These raptors seldom prey upon prairie-chickens, but their persistent harassment of the chickens in fall made territorial display, and therefore fall censusing, virtually impossible. Up to 15–20

Female prairie-chicken leaves nest of eggs in more peaceful days on the sanctuary (photo by R. E. Hesselschwerdt).

raptors were observed on or near the main booming ground.

Why were harriers and short-eared owls so numerous on the sanctuaries last winter? The answer to that question came as a result of an intensive study of prairie voles (*Microtus ochrogaster*) by biological anthropologists Drs. S. J. C. Gaulin and R. W. Fitzgerald of the University of Pittsburgh. In conducting a segment of their nationwide study on one of the sanctuaries, high densities of about 300 voles/ha were found in the grassland chosen for their studies. Because the study site was representative of many of the sanctuary meadows, high densities of voles were likely on other sanctuaries. Prairie voles are a mainstay in the diet of harriers and shortears, so vole abundance evidently attracted unusually high numbers of raptors to the sanctuary grasslands, which in turn caused disruption of the booming ground and difficulties in censusing.

Unfortunately, the prognosis for spring 1987 is not good. Only 24 males, about 40 total prairie-chickens, were observed this fall on the sanctuary area in Jasper County. Unlike the fall of 1985, no interactions with raptors have been noted this fall, so the autumn census should again be closely predictive of the spring populations — probably the lowest level since preservation efforts were begun in the early 1960's. Interactions between pheasants and prairie-chickens have been identified as currently posing the greatest single threat to the survival of the prairie-chicken in Illinois. In the absence of interventions to control numbers of pheasants on the sanctuaries, the survival of our remnant prairie boomers appears unlikely.

By *R. L. Westemeier, Wildlife Research Section*

Root systems of mature trees can be easily observed when large trees are blown over by big violent windstorms (photo by Gene Himelick).

Root Development of Trees Growing in an Urban Environment

Rapid regeneration of the root system is the most important factor for the successful establishment of transplanted trees and shrubs. Several field studies have been conducted during the past 10 years to better understand root development of established trees, and how root growth relates to successful transplanting practices in the urban development.

To maximize survival, a favorable root-shoot ratio must be quickly established after transplanting. Since a new root system must regenerate from the remnants of the original root system, the roots of several different tree species were excavated to determine their pattern of distribution and development before and after transplanting. The field data indicate that nursery-grown trees lose from 95 to 98 percent of their total root system when being transplanted with a soil ball. Most root regeneration after transplanting was found to originate near the severed root ends and that root development below 12 inches appeared to be limited depending upon the soil type. Those tree species tending to be more deeply rooted were found to be less tolerant to heavy clay urban soils having seasonably high water content during the spring months. Also, shallow-rooted tree species were not tolerant of urban soils where the upper soil layers were subjected to long dry periods during summer droughts.

There are large differences among tree species in their capacity for root development. Even within the same tree species there exists heredity differences in root growth. Root form, as well as depth and growth rate, are markedly influenced by the rooting medium. For example, young trees 5 to 10 years old, growing in sandy loam soil, will produce an average of 15 to

20 inches of root growth per year, whereas in clay soil, root growth will average 2 to 10 inches. Tree roots normally spread laterally well beyond the width of the crown. In many tree species, roots extend laterally about 3 times as far as the crown when growing in sand, about 2 times in loam soil, and in clay soil about 1.5 to 2 times. Large cottonwoods, for example, have been observed to form lateral roots for more than 200 feet.

The major part of a tree root system consists of large perennial lateral roots and short-lived small roots. There is controversy about the reasons for the death of small roots. Some investigators believe the death of small roots to be normal physiological abscission. Others believe that unfavorable soil, environmental conditions, pests in the soil, and certain fungi and bacteria may be responsible. Defoliation from diseases or insects will increase mortality of small roots. Even in apparently healthy trees, the loss of small roots often occurs shortly after they are formed.

Many of the small absorbing roots of trees are confined to the soil surface layers. Numerous field data and observations support this among trees growing under forest conditions, and more especially those trees growing in an urban environment. Depending upon the type of urban soil, as much as 90 percent of the roots less than ⅛ inch in diameter are growing in the upper 6 inches of soil. For most tree species, 80 percent of the total root volume will be found in the top 12 inches of soil. Specialized roots, called sinker roots, often penetrate to depths of 3 to 4 feet, but their volume and absorptive areas are only a fraction of the total active tree root system. The importance of tap roots has been overemphasized. Under urban soil conditions, no tap roots have ever been observed; many small sinker roots were frequently found when examining the roots of large trees growing in urban soils.

Grass competition was found to be especially detrimental to trees growing in areas where the topsoil was shallow. Limiting grass competition by mulching with wood chips has been found to be beneficial to tree root development. Mulching is frequently recommended when the health and vigor of a tree becomes more important than the grass.

By *Gene Himelick,*
Botany and Plant
Pathology Section

What's Happening to the Pine Trees?

Pine trees are dying in Illinois, particularly Scotch and Austrian pines. They are dying because of a disease called pine wilt, which is caused by the pinewood nematode and its associated organisms. The first record of the disease in Illinois was in 1979. Since then the disease has been reported in 55 counties throughout the state. Pine wilt is common throughout the Mississippi Valley and eastward. The disease has been confirmed in 21 pine species and in larch and spruce. Scotch, Austrian, and red pine appear to be the most susceptible. Some cases of the disease have been confirmed in white pine, but white pine appears to be less vulnerable. Researchers at the Survey have been investigating several

A largehorned beetle (lower right half of picture) feeding on a pine branch (photo by James E. Appleby).

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aspects of the spread of the nematode. They discovered that a longhorned beetle, the Carolina pine sawyer, is the most important vector, or carrier, in transmitting the nematode from diseased to healthy pines.

The body of the adult beetle is about ½ inch long with antennae often longer than its body. The general color is dark brown with some patches of a lighter tan. During the late spring and summer months, the female beetles deposit eggs on the trunks of dying or recently dead pine trees. The eggs hatch and the beetle larvae develop under the bark. By late summer they bore into the heartwood of the tree where they remain until the following spring. In late spring an interesting phenomenon occurs in trees that have been infested with the pinewood nematode. Thousands of nematodes accumulate in the wood near the beetle larva while it is changing into the pupa stage. The pupa stage of the beetle may last from 2 to 5 weeks depending on the temperature.

When the beetle changes into the adult state just prior to its emergence from the wood, thousands of nematodes invade the spiracles or breathing pores of the beetle. The adult beetle then acts as a vector, or carrier, of the nematode. The adult sawyer beetle then flies to the smaller pine branches of a healthy tree and begins feeding. The chewing of the beetle on the smaller branches causes small wounds. During the time when the beetle is feeding, some of the nematodes leave the beetle's body and enter the wounded pine tissues. Blue stain fungal spores are nearly always present on the body of the beetle and they probably enter the wound area as well. Soon after the nematodes enter the pine tissues they multiply at a fantastic rate.

About 6 weeks after the initial nematode invasion, the pine needles begin to turn a light grayish-green. This is the symptom that indicates the tree is doomed. Usually about 3 to 4 weeks later the needles turn brown and the tree is dead. Female longhorned beetles are attracted to such a tree and the cycle is repeated. In central Illinois investigators have found that adult beetle emergence occurs from late May until early August and that the beetle's average life is about 2 months. In recent studies a visiting Japanese scientist, Katsumi Togashi, found that a few beetles are capable of living as long as 120 days and are capable of transmitting the nematodes over this entire time. Protecting pine trees for such a long period will be difficult. Promptly removing all dead and dying pine trees and disposing of the wood either through burning or covering with soil, as done in a sanitary landfill, are the present recommendations to prevent further spread of this disease.

By *James E. Appleby,*
Section of Economic
Entomology

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NATURAL HISTORY
SURVEY REPORTS

JANUARY 1987, NO. 263

Lorin I. Nevling Appointed Chief

Dr. Lorin I. Nevling is the new Chief of the Illinois Natural History Survey, a Division of the Department of Energy and Natural Resources (DENR). The Board of Natural Resources and Conservation, the governing body of the three scientific surveys and the state museum, appointed Dr. Nevling to succeed Acting Chief Lawrence Page.

"Dr. Nevling has outstanding credentials as a scientist, an administrator, an author, and a leader," said Don Etchison, Board chairman and DENR director. "The state of Illinois, the Department of Energy and Natural Resources and the scientific surveys are fortunate to have as the new chief of the Natural History Survey a man with such a distinguished international record of achievement."

As the former Director of the Field Museum in Chicago, Dr. Nevling is a seasoned administrator who has had extensive experience in the arts, humanities, and science. He left Harvard University in 1973 to become Chairman of the Deparment of Botany at the Museum. He advanced to the position of Assistant Director for Science and Education, and in 1980 he became Director of the Museum.

He was at Harvard University from 1959 until 1973 where he was employed by the Arnold Arboretum, the Gray Herbarium, and the Farlow Herbarium. Besides conducting extensive research in the United States and abroad, Dr. Nevling has authored more than 75 scientific articles, serves on several boards, and holds many professional appointments.

DR. LORIN I. NEVLING

As he assumed his duties at the Survey, he said, "For more than 125 years, the Illinois Natural History Survey has provided the scientific knowledge necessary to secure the preservation of our natural heritage for future generations and to guide the prudent choices for the wise use of our biotic resources.

"I am pleased that I have been selected for the leadership role of the premiere state natural history survey in the nation and look forward to a productive relationship with the Survey's outstanding scientific staff."

Dr. Nevling was a graduate of Saint Mary's College in Winona, Minnesota with a B.S. degree in biology in 1952. Following 2 years service in the military, he earned his Master's degree in 1957 and his Ph.D. degree in 1959 from Washington University, St. Louis, Missouri.

Dr. Nevling is the sixth in a series of outstanding men who have served as Chief. The Chiefs and their years of

service were Stephen A. Forbes, 1917-1930; Theodore H. Frison, 1931-1945; Harlan B. Mills, 1947-1966; George Sprugel, Jr., 1966-1980; and Paul G. Risser, 1981-1986.

By *Shirley McClellan, Public Relations Officer, with excerpts from news release of the Department of Energy and Natural Resources*

World in the Willows

The pussy willow, *Salix discolor,* Muhlenburg, is a much prized ornamental by Midwesterners because the appearance of the silvery catkins of the male plants in the spring is a sure sign that warmer weather is just around the corner. However, few homeowners realize that the plant is home to a number of insects and other arthropods. If the stems of the current year's growth on female plants are examined carefully, one can often find irregular swellings which are stem galls caused by larvae of the agromyzid fly, *Hexomyza salicis* (Malloch). The biology of *H. salicis* is interesting because it is a stem-galling species with only one generation per year in contrast with the leaf-mining, multigenerational crop pests upon which nearly all of the detailed biological investigations of members of this family have been conducted.

Adult *Hexomyza* emerge from the willow stems in early May, about the time the pussy willow is shedding its seeds. They are quite short-lived compared to other agromyzids and live an average of 3 days. During the few days the adult flies are out, they can be seen mating and ovipositing on the current year's growth of the willow. The flies never stray far from the willow plants.

The spindle-shaped eggs are laid with their long axis parallel to the stem just below the bark in the cambium layer of the willow stems. They hatch in about 2 weeks and the tiny first instar maggots establish themselves in small chambers dug just beneath the bark. The maggots feed and grow throughout the summer. Their activities cause the part of the stem over their chambers to swell, producing the gall. In late October, the maggots become immobile and begin to swell, taking on the appearance of tiny, shiny white sausages. They overwinter inside the stems in this swollen form.

The maggots become active again in the spring and do more feeding. In early to mid-May, the maggots begin digging out through the stem to the outermost dry dead layer of bark, leaving an operculate flap which can be pushed open by the adult fly. The maggots then retreat back to the center of the gall, pupate, and emerge as adults 3 weeks later.

If carefully examined under a microscope, about one-third of the *Hexomyza* larvae show a distinct green object in the posterior part of their bodies. This green object is the gut contents of the first instar larva of a new species of hymenopterous parasitoid in the genus *Sphegigaster* (Pteromalidae).

In the early summer, the female wasps lay their eggs into early first instar *Hexomyza* maggots. The eggs hatch within a

Cross-section of a willow stem gall showing larva of *Hexomyza salicis* which contains the larva of a parasitoid wasp (*Sphegigaster*) visible as a dark blob in the lower fourth of the *Hexomyza* (photo by Steve Heydon).

A branch of pussy willow showing the gall of *Hexomyza* on the lower part of the middle twig. This twig has died and the lateral twigs have replaced it (drawing by Steve Heydon).

week, but the wasp larvae suspend their development and remain quiescent within the fly maggot throughout the summer, fall, and winter, until the next spring. The wasp larvae resume development about the time their host maggot begins to pupate. They grow rapidly and consume the full-grown fly maggot in a period of a few days. Adult *Sphegigaster* emerge just after all the *Hexomyza* adults have died. In contrast to their hosts, the adult wasps are long-lived and may survive for as long as a month.

Hexomyza maggots also have another parasitoid. This one is another wasp in the genus *Eurytoma.* The female *Eurytoma* lays her eggs into the chamber containing the fly maggot. The egg soon hatches and the wasp larva immediately attacks the fly maggot and consumes it. The wasp larva then completes its development by eating the plant tissues of the gall. The *Eurytoma* larva pupates and emerges without delay so there is more than one generation per year.

Fortunately for florists and homemakers, male willow bushes have very few galls despite the fact that they are acceptable as oviposition sites. One of the reasons male plants have fewer galls is that the newly hatched *Hexomyza* maggots are only half as likely to become successfully established in their chambers in male stems as they are in female stems. Those maggots that do get established almost invariably die during the summer. So, we have a case of sex-related difference in resistance to galling. This difference has a significant effect on the plant architecture of the two sexes of the pussy willow. The shoot of a female plant, galled the previous year, shows very little growth beyond the gall during the succeeding year and often dies back. Most of the new growth along that stem comes from auxillary buds below the gall. These shoots will be galled by the flies emerging from stems galled during the previous year and will fail to grow the next year. This pruning effect produces more stems for the flies to oviposit into, but it also produces bushy, female plants in contrast to the treelike male plants.

Another interesting observation is that *Hexomyza* oviposition scars are concentrated around the stipules at the bases of the leaf petioles. The eggs lie in the stem at a distance of a millimeter or so from the oviposition scar so the eggs end up lying right under the leaf stipules. This protects them from parasitism by *Sphegigaster* and *Eurytoma,* since the female wasps must straddle the region of the stem just above the maggot in order to successfully parasitize it.

By *Steve Heydon and W. E. LaBerge, Section of Faunistics Surveys and Insect Indentification*

Society Publishes Second Issue of *The Nature of Illinois*

The Society for the Illinois Scientific Surveys (SISS) has published the second

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issue of *The Nature of Illinois,* a quarterly magazine dedicated to informing the public about the important research conducted by the Natural History, Geological, and Water Surveys. The Society is a not-for-profit organization with the goals for building a constituency for the Surveys and providing a program through which citizens of Illinois can better understand the natural resources of the state.

Membership in SISS is open to anyone who subscribes to the purposes of the Society at $25.00 a year for an individual and $50.00 a year for a family by writing the Society for the Illinois Scientific Surveys, 2021 Illini Road, Springfield, IL 62704.

Jane A. Bolin is the Executive Director; Linda Classen Anderson, Assistant Director; William Rooney, Communications Consultant; and Gaylord Donnelly, Chairman of the Board of Directors.

By joining SISS, subscribers will help to build an organization that promises to support our future activities and, by receiving *The Nature of Illinois,* will be able to keep abreast of research activities in all three Surveys.

By *Lawrence Page,*
Acting Chief,
December 1986

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Illinois
NATURAL HISTORY
SURVEY REPORTS

FEBRUARY 1987 NO. 264

Artificial Perch Sites for Bald Eagles

The Mississippi River Valley is a major wintering area in the United States for the federally endangered bald eagle. After the nesting season, bald eagles from Canada, Minnesota, and Wisconsin move southward along the river into their winter range. In the Midwest, immature eagles move southward earlier than adults, arriving in Illinois by September or October. Eagle populations in Illinois reach maximum numbers during January and early February when temperatures are lowest. Wintering eagles are last seen in March or April.

Dams on the Mississippi River concentrate wintering bald eagles because they provide ice-free water from which the eagles obtain their principal food, dead or dying fish. In Illinois, gizzard shad are a main food item because of large winter die-offs.

An adult bald eagle resting on a branch of an artificial perch tree (photo by Glendy Vanderah).

Construction of Lock and Dam #19 on the Mississippi River in 1913 significantly increased wintering bald eagle populations between Hamilton, Illinois and Keokuk, Iowa, and it has become one of the better known bald eagle wintering areas in Illinois. Cedar Glen, located on the floodplain south of the lock and dam (purchased by the Nature Conservancy in 1970), is an important bald eagle night roost. Such favored roost areas, providing protection from wind and precipitation, are essential features of bald eagle winter habitat.

Location of preferred diurnal perch sites, usually separate from nocturnal roosts such as Cedar Glen, also influence the distribution of bald eagles within their winter habitat. Eagles use diurnal perches for three basic activities: loafing (resting or preening), foraging, and eating. Preferred perch trees are tall and sturdy and usually are near a food source on an open edge such as a riverbank. Suitable perches are easily accessible to eagles and provide a good view of the surrounding area. The growth forms of floodplain tree species such as cottonwood, silver maple, and sycamore (especially snags) are favored by bald eagles.

In 1984 the Illinois Department of Transportation (IDOT) completed construction of a four-lane bridge spanning the Mississippi River between Hamilton and Keokuk. Relocation of the bridge and re-routing of U.S. Route 136 ne-

Artificial perch trees located along the shore of the Mississippi River at Hamilton, Hancock County, Illinois (photo by Glendy Vanderah).

cessitated removal of bald eagle diurnal perch trees in the floodplain forest on the Illinois side of the Mississippi River. The mitigation measure to compensate for tree loss was the erection of artificial perch trees on the Illinois shoreline downstream from the new bridge. The success of artificial perch sites erected in recent years in other states has been questionable, suggesting that different artificial perch designs and their usefulness to bald eagles needed further study.

After 2 years of design modification and additions to the perches, six artificial perch trees now stand south of the new bridge, in an area that previously was devoid of adequate eagle perch trees. The artificial perch trees, set in concrete into the riverbank, are of three types: unmodified cottonwood snags (3), telephone poles that have been modified with snags and branches (2), and a cottonwood snag modified by the addition of branches (1).

Patti L. Malmborg and Glendy C. Vanderah, ornithologists in the Section of Faunistic Surveys and Insect Identification, are studying these artificial perch trees in cooperation with IDOT and the Illinois Department of Conservation to assess their value to bald eagles wintering in the Lock and Dam #19 area. Data on bald eagle activities in the vicinity of the artificial perches will be collected throughout the 1986-1987 winter. Comparisons will be made between bald eagle use of artificial versus natural perches and possible preferences for specific artificial perch designs. Since the study began in mid-November, increasing numbers of eagles have used the artificial perches. At this early date, the eagle population has not yet reached its maximum, and immature eagles outnumber adults. When the study is completed next March, the researchers will evaluate the effectiveness of the artificial perches. This information will be useful for future decisions concerning mitigation measures and management of bald eagle wintering areas.

By *Glendy C. Vanderah*
Section of Faunistic Surveys and Insect Identification

Illinois Component of the National Wetlands Inventory

A century ago the land surface of Illinois was characterized by an abundance and diversity of wetlands. These areas represented intermediate successional stages between open water and

dry land such as marshes and swamps. Today about 95 percent of the natural wetlands of the state have been drained or otherwise destroyed, and that trend continues at a rapid pace. Waterfowl and other forms of wildlife use wetlands extensively, and many of Illinois's endangered, threatened, and rare species depend on the remaining wetland habitats for survival. Recently other values and functions of wetlands have been recognized: flood control, stream and aquifer recharge, water quality improvement, renewable sources of food and fiber, and scientific and recreational pursuits.

Currently, wetlands in Illinois are not protected. Certain federal and state laws indirectly contribute to wetland protection by requiring a permit for dredge disposal, construction, or other activities within stream channels or floodplains. Farm bill legislation passed recently denies program benefits to any person who converts wetlands to agricultural production, the most common fate of wetlands in the past. Some Illinois wetlands are protected by inclusion in the state nature preserve system, or are under public ownership as wildlife refuges, conservation areas, or state parks. The Illinois Natural Areas Inventory identified most of the high quality wetlands in the state, but affords no protection to them. The owner of a natural area may participate in the Natural Heritage Landmark Program or enter into a conservation easement agreement to protect a wetland from development or alteration.

Increasing public awareness of the value of wetlands and concern over the rapid decline of this unique resource has stimulated support for a comprehensive program for wetland protection and management in Illinois. The Natural History Survey and the Department of Conservation have initiated a joint project with the U.S. Fish and Wildlife Service to locate and classify the remaining wetlands of the state. The Illinois Wetlands Inventory is one component of a larger National Wetlands Inventory

On the left, a typical wetlands area near Lake Sangchris in central Illinois (photo by Lance Perry).

Wetlands are mapped and classified according to a nationally standardized system. The figure to the right shows a computer graphical representation of wetlands polygons with their coded types.

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(NWI) being conducted on a state-by-state basis by the Fish and Wildlife Service. A national hierarchial system classifies wetlands and deepwater habitats based on ecological characteristics. A wetland must meet at least one of three criteria: 1) presence of typical wetland plants (hydrophytes), 2) presence of wetland (hydric) soils, or 3) substrate, if nonsoil, saturated or covered with water at some time during the growing season each year. All identifiable wetlands are initially delineated on color infrared photographs produced by the National High Altitude Photography program. The photo scale (1:58,000) allows detection of wetlands smaller than an acre. Photo interpretation is followed by extensive field checks to verify identifications. Final products depict all wetland locations and classifications on standard 7.5′ quadrangle base maps in either paper or digital form. To date 106 quadrangles in northeastern Illinois have been received. The remaining quadrangles of the state will be received over the 4-year life of the project.

The participation of the Natural History Survey places Illinois at the forefront of the NWI. Instead of relying on wetland maps in typical paper form, Survey researchers Lance Perry, Liane Suloway, and Warren Brigham are receiving the data in a digital format compatible with the computer-based Geographic Information System (GIS) maintained by the Department of Energy and Natural Resources. This will allow for custom design and display of map products, efficient retrieval of data summaries, and analyses of spatial relationships between wetlands data and other natural resource, infrastructural, and administrative data held in the GIS. The addition of an automated wetlands database to the state GIS will give Illinois unprecedented capability for protecting and managing the state's wetland resources.

By *Lance G. Perry*
Aquatic Biology Section

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NATURAL HISTORY SURVEY REPORTS

Chicago Urban Deer Study

White-tailed deer are currently dispersed throughout Illinois having made a dramatic comeback since being essentially extirpated in the state during the late 1800's. In 1957, numbers were high enough in selected counties to allow public-regulated hunting. Currently, deer herds are managed by firearm hunting in 98 of the 102 counties in Illinois. The remaining four counties include the highly urbanized area of northeastern Illinois — Cook, DuPage, Kane, and Lake counties — where deer thrive in an area of intense human development where literally millions of people work and reside.

Since the fall of 1983, Jim Witham and Jon M. Jones of the Illinois Natural History Survey (INHS) have studied the white-tailed deer in northeastern Illinois. The work, sponsored by the Illinois Department of Conservation (IDOC), is a long-term program that will contribute to future urban deer management decisions in the Greater Chicago Metropolitan area. On a general scale, the research objectives are to build a data base on the life history and ecology of local herds, to evaluate the availability and distribution of deer habitat, to assess deer-related damage, and to develop and experiment with alternative management strategies. Completion of re-

Deer and high rises occupy same areas in Metropolitan Chicago area. Deer become tamer every day as they strive to reclaim areas that were once theirs alone (photo by Jim Witham and Jon Jones).

search is projected for July 1989.

Field and lab work have dominated project activities. For the first 2 years concentration was placed on building a data base from which interherd comparisons could be made. With what is referred to as the "infamous carcass collection program," the help of 90 agencies and individuals was enlisted to acquire deer carcasses for postmortem evaluations. A majority of specimens were struck by vehicles; however, responses were made to all reports of carcasses. In 23 months over 1,000 deer carcasses were collected. Analyses of data collected during postmortem examinations are not completed but some interesting material has been documented.

Deer in northeastern Illinois displayed a wide range in average condition or herd quality. Specimens from high density herds typically exhibited classic symptoms of chronic malnutrition — low body weight, stunted skeletal structure, small antlers, less fat, and low fetal counts. Herds generally displayed old-age structure with considerable difference between the maximum recorded longevity of bucks (8 years) and does (14 years). In contrast, animals from lower density herds were more robust and were more productive.

Sue Wood, INHS Chemical Analytical Laboratory, tested tissues taken from deer in northern Cook County for the presence of heavy metals, pesticides, and PCB's. Although a wide array of toxicants were detected, concentrations were below levels believed to be harmful to deer or for human consumption. A similar conclusion was made regarding the parasite loads of these same deer. Parasites of deer were found, roundworms being most common, but numbers were not excessive nor were species atypical.

Over 200 deer were live-captured, marked, and released. As a result of observations of marked deer, it is known that a large percentage of the deer, particularly females, in the high density herds of Busse Woods and the Des Plaines River, were highly sedentary. Thirteen does that were relocated by telemetry for 2.5 years on the Des Plaines River, showed no dispersal. In the Ned Brown Preserve, no evidence was found of dispersal among females. Greater occurrence of dispersal was expected.

Recoveries of collars and resightings of live animals have permitted investi-

Gone are the days of the deer's natural habitat as the animals struggle to survive in areas also occupied by humans (photo by Jim Witham and Jon Jones).

gators to estimate sex and age specific survival rates by season. A most interesting finding was that 30 percent of 53 marked bucks in the Ned Brown Preserve were struck and killed by vehicles. Deer-vehicle accidents have increased in Cook, DuPage, Kane, and Lake counties during the last decade. Illinois Department of Transportation (IDOT) records show that Cook and Lake counties ranked first and second in the number of deer-vehicle accidents. DuPage, Kane, McHenry, and Will counties also rank high in the number of recorded deer-vehicle accidents. A questionnaire sent to individuals that struck deer with their vehicles during 1985 indicated an average loss of $1,306.00 per accident.

Aerial censuses were conducted each year. Researchers now have a better appreciation for problems associated with flying in the congested airspace of northeastern Illinois. Deer densities were high in areas least accessible to aerial census — preserves within the terminal control area of O'Hare International Airport. Densities ranged from less than 1 deer/km^2 (1-2 deer/mi^2) to about 50 deer/km^2 (130 deer/mi^2). Deer numbers on the Ned Brown (Busse Woods) and the Des Plaines River preserves were exceptionally high. Such densities far exceeded the ability of the existing habitat to support deer on a sustained basis. Other areas where deer numbers approached critical densities include Palos-Sag Valley and Waterfall Glen/Argonne.

The effects of deer browsing on native vegetation were dramatic in the high density sites. Heavy browsing pressure had decimated the forest understory vegetation. The public can readily observe distinctive browse lines created by deer on vegetation adjacent to Interstate 90 (Ned Brown) and Interstate 294 (Des Plaines River). What plants are missing from these systems? How long will it take for the excessively browsed plants to regenerate? Will the same plants return, or will more aggressive weedy species predominate? These are some of the questions that need to be answered. Based on the very slow plant regeneration that has occurred in two deer-proof exclosures that were built 3 years ago, regeneration of forest understory vegetation on impacted sites will be a long, slow process.

Warning highway signs and vehicle-killed deer are a familiar part of the landscape in and near Chicago (photo by Jim Witham and Jon Jones).

The Ned Brown Preserve was selected for intensive study because it contained the greatest number of factors needed to meet research objectives — the area had a very large deer herd, browsing pressure had substantially impacted the structure and composition of forest understory, deer-vehicle accidents were common, and the herd was essentially a closed population because of extensive developments on adjacent properties. Also, within the Ned Brown Preserve is the Busse Woods State Nature Preserve and federal natural landmark — a priceless 177 ha (440 acres) remnant of native vegetation.

As part of the research program, an experimental pilot study of deer-herd reduction was implemented in late 1985. The framework of this plan was presented at two public meetings of the Illinois Nature Preserves Commission. Support for the pilot deer removal study was received from the Illinois Nature Preserves Commission, the Cook County Forest Preserve District, and the IDOC — with recognition also given by members of the Urban Deer Study Com-

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munity Liaison Committee. The primary objectives of the deer removal program were to: (1) reduce browsing pressure to a level that would allow regeneration of forest trees and understory plants, (2) significantly reduce the number of deer-vehicle collisions on adjacent roads, and (3) significantly improve average herd condition/health.

Herd reduction was designed in a manner that evaluated the cost-effectiveness of a series of removal techniques. These included both lethal and live-capture methods. Some deer were shot by professional marksmen; other deer were live-captured with rocket-nets and drive-nets. Herd reduction goals were achieved in April 1987. Computer models will be used to estimate herd demographic parameters and will improve the researchers abilities to predict future changes which may impact the Busse Woods Nature Preserve.

The disposition of carcasses of deer taken by shooting during herd reduction has been rewarding. Over the past year, the INHS, in cooperation with the IDOC and other state agencies, has solved some of the complex legal problems associated with donating game carcasses to charitable institutions. Researchers now work closely with the Greater Chicago Food Depository, a not-for-profit organization, that distributes food to over 500 missions and soup kitchens that feed the indigent of Chicago. Although public utilization of deer carcasses collected as a result of INHS research is viewed as an experimental test case, initial efforts have met with solid approval from agencies and the public.

Deer that were live-captured have been transported to a site in Will County and released in cooperation with the U.S. Department of the Army. This study segment was designed to evaluate the movements and survival of translocated deer. From these translocations, investigators have been able to determine the cost-effectiveness of using live-capture and translocation as a removal, or herd control, technique.

Where do we go from here? The research program is pushing into a monitoring and data synthesis phase. Reports are being condensed into technical and popular publications. Key environmental factors, particularly those useful for management, will continue to be measured. The current project will conclude in 2.3 years with a final report that integrates all aspects of a 6-year effort.

It is clear that the urban deer problem is real and that it will not diminish. If a residual cooperative management structure — one that involves state, county, and local governments — can be developed, then the data generated during this program will provide an invaluable biological basis on which management decisions can be derived.

By *James H. Witham*
Jon M. Jones
Section of
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The Illinois
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The Asian Invader

The Asian tiger mosquito, *Aedes albopictus*, was collected first in the continental United States in Houston, Texas in August, 1985. This mosquito arrived in Houston in used truck and automobile tires brought from Asia for reprocessing to obtain natural rubber, petroleum extracts, and recapping. By the fall of 1986 it had spread, again by means of used truck and automobile tires, throughout the southern United States and into the Midwest from East St. Louis to Greenville, Ohio. *A. albopictus* is a native of the Orient. The strain of mosquito that entered Houston apparently came from northern Japan. Preliminary indications are that it has the capacity of overwintering and becoming established as far north as Chicago.

A. albopictus is an aggressive and voracious biter and has the capacity to become a serious public health threat. In its Asian habitat it is an efficient carrier of several viruses that cause disease in man, such as dengue fever, which can produce hemorrhagic manifestations. In this hemisphere dengue is widespread throughout Central America, the Caribbean, and northern South America. Historically, major epidemics of dengue fever have occurred along the Gulf Coast and inland as far north as Memphis, Tennessee.

Because *A. albopictus* is an efficient carrier of many viruses and because it takes blood meals from birds and mammals, as well as man, there is a strong possibility that this mosquito may become involved in the transmission of St. Louis Encephalitis and LaCross Encephalitis. Laboratory studies with *A. albopictus* have shown that these two viruses can also be transmitted from one mosquito generation to the next through the eggs. Added to this is the fact that this mosquito is one of the primary transmitters of dog heart worm in Asia. This parasitic worm of dogs is a major problem throughout Illinois.

The pestiferous biting behavior of this mosquito, coupled with its potential disease-carrying capabilities, could create a severe personnel and economic burden on mosquito abatement districts as well as public health and veterinary agencies.

Biologically, *A.albopictus* is a forest mosquito that has adapted to living in and around domestic environments. Females require a blood meal to produce eggs that are laid just above the water line in either man-made containers, such as tires, cans, flower pots, or natural containers, such as treeholes. Mosquito eggs are very resistant to desication and may remain alive for extended periods of

The Asian tiger mosquito, *Aedes albopictus*, which has invaded the United States (photo by Dr. Leonard Munstermann, University of Notre Dame).

time. Flooding the eggs with water stimulates hatching. The immature stages (four larval stages and one pupal stage) are all aquatic, but require direct access to air for respiration. Flying adults emerge from the aquatic pupal stage. The life cycle from egg to adult can take as little as 7 days depending on the temperature.

Since *A.albopictus* is a forest mosquito, the possibility of it moving into treeholes in Illinois is very likely. This mosquito is a fierce competitor and has the capacity to disrupt or alter our natural fauna. The displacement of local species of mosquitoes by *A.albopictus* has already occurred in Texas and Louisiana. The long-term environmental effects of species replacements have been topics of question to biologists and naturalists for many years.

It is difficult at this time to predict the magnitude of impact that *A.albopictus* will have in Illinois, in relation to human and animal disease transmission, changes in our natural fauna, or in the operations of insect control agencies. However, the importation and rapid spread of this insect in the United States shatters the idea that we are isolated from exotic pests and diseases. Illinoians are especially vulnerable having within the State a major hub of international air traffic and extensive river and lake transport systems.

The Illinois Natural History Survey, in collaboration with the Illinois Department of Public Health, is developing a program to study the distribution and biology of this mosquito. Studies which will begin this summer include a county by county survey to establish its distribution and spread. A major project will be to determine if and where this mosquito can successfully overwinter in the State. Information gained from these studies will be used to help establish control guidelines.

By *R. J. Novak & D. W. Webb*
Section of Faunistics
and Insect Identification

Conservation Tillage: Potential Benefits for Illinois Wildlife

With the current emphasis being given soil and water quality goals, conservation tillage has become a byword to farm producers in Illinois. Traditionally, corn and soybean fields dominating rural landscapes have attracted resident and migratory wildlife, because of the abundant forage of waste grain seeds left during harvest. However, with the adoption of more efficient harvest machinery and tillage implements in recent decades, wildlife biologists have become concerned about the general availability of these high-energy waste grain foods for wildlife.

From 1981–1985, R. E. Warner, S. P. Havera, and their associates considered the seasonal availability of waste corn and soybeans in central Illinois relative to historical and contemporary agronomic practices. Their research indicated that on the average, about 6 percent and 8 percent of the harvested corn and soybean yields, respectively, are currently left on the ground at harvest. Since World War II, the efficiency of crop harvest machinery has improved; but in terms of waste grain abundance, increasing yields have compensated for improved harvest efficiency. The net effect is that corn and soybean harvest gleanings remain abundant, and that the availability of waste grains for wildlife is closely related to tillage practices and environmental conditions that affect the decay of seeds on the soil surface.

Compared to corn and soybean fields that were not disturbed by machinery following harvest, fields receiving fall conservation tillage (discing and/or chisel plowing) typically have 70 to 80 percent less waste grain and 50 to 60 percent less plant litter protecting soil surfaces from fall harvest up to planting time the following spring. Leading up to winter, environmental conditions such as temperature and moisture play a major role in determining the relative abundance of waste grains. Relatively warm temperatures and moist soils foster high rates of sprouting and decay of grain seeds—especially for soybeans. During the 4- to 6-week period from harvest to early December, about 36 percent of the waste corn and 71 percent of the waste soybeans disappear in a typical untilled field.

Fall tillage in addition to other factors causing waste grain disappearance ren-

der many, if not most, such fields that are disturbed by farm field operations before spring, unattractive to foraging wildlife. In order to make comparisons of various conservation tillage systems and their relative attributes as wildlife habitat, mathmatical models were developed based on data for all years and seasons in central Illinois, 1981–1985. The table compares waste grain food abundance and amount of harvest residues protecting soils from erosion for corn tillage systems commonly used in Illinois. These results illustrate the progressive seasonal decline in waste grain abundance that occurs in crop fields and the highly variable effects of different tillage practices.

Soil and water quality goals in Illinois generally require that crop residues cover at least one-third of the soil surface after spring planting. The table indicates that there are many conservation tillage practices that do not adequately protect soils after planting; multiple-pass tillage operations rarely leave sufficient protective residues. Further, soybean residues are more fragile than corn, and in general any form of fall tillage will render these fields inadequately protected from erosion following spring planting. The results generally show that row-cropping practices that meet soil and water conservation guidelines are likely to offer an attractive food base for wildlife in Illinois.

Table 1. Generalized comparisons of corn tillage systems commonly used in Illinois in relation to protection from soil erosion (% ground covered by crop residues), and the abundance of waste corn (kg/ha) potentially available to wildlife.

Season & Tillage Practice	Ground Cover (% residue)	kg/ha (dry weight)
HARVEST (17 Oct.)	97	353
EARLY WINTER (30 Nov.)		
Untilled	95	255
Disk(tandem)	88	191
Chisel (straight shank)	75	119
Chisel (twisted shank)	40	31
Chisel + disc	16	9
EARLY SPRING (2 Apr.)		
Untilled	88	155
Disk (tandem)	79	107
Chisel (straight shank)	67	67
Chisel (twisted shank)	36	17
Chisel + disc	14	5

By *R. E. Warner & S. P. Havera*
Section of Wildlife Research

The Celery Webworm

The celery webworm, *Nomophila neartica*, has a worldwide distribution including Europe, Africa, South America, and most of the United States. In certain parts of the United States the insect is of considerable importance due to defoliation of forage crop plants. In east central Illinois, the insect is very common in both turf and grassy areas. Studies by Felt (1893) in New York, Flint (1922) in Illinois, and Smith (1942) in Kansas provided some information on the insect's life history and feeding habits; however, very little work has been conducted on developmental rates as affected by temperature, seasonal abundance, natural enemies, and overwintering habits.

In order to learn more about the habits and biology of the celery webworm, a study was initiated in cooperation with Joe Maddox, an insect pathologist with the Survey, to determine developmental rates as affected by temperature, seasonal abundance, and food plant preference of the webworm in the east central Illinois area. Celery webworms collected from field-captured females were placed in growth chambers set at six different temperature regimes. Once the eggs hatched, the young larvae were placed on an artificial diet and observed for molting. Written records were kept on time of molting, and larval head capsules were collected for future measurements. Pupation and adults emergence were also recorded for all temperature regimes. Preliminary growth chamber developmental studies

The celery webworm, *Nomophila neartica*, will appear in Illinois normally in mid-June, but sometimes as early as May and as late as the end of July (photo by Fredric Miller).

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revealed an egg threshold temperature of 8°C., a larval threshold of 14°C., and a pupal threshold of 11°C.

To determine the seasonal abundance of the celery webworm, two blacklight traps were stationed at two separate locations near the University of Illinois campus. The traps were checked every 2 to 3 days and the total number of celery webworms counted. Based on these light trap catches, peak emergence occurred in mid-June to late June when over 1,500 moths were collected in a 1-week period. Smaller catches were collected in early May and late July through early August but were not distinct enough to be considered as separate generations. These findings are in contrast to findings by previous studies in which Flint (1922) and others speculated that there may be two to four generations per season in the Midwest. However, no light trap data was collected to substantiate these conclusions.

Previous researchers have indicated a rather wide food host range for the celery webworm including sweet clover, red clover, alfalfa, bluegrass, purslane, corn, wild mustard, and foxtail. Feeding studies were conducted in an attempt to determine the major food plants fed on by the celery webworm in east central Illinois. Individual larvae were placed in individual glass vials and fed either bluegrass, alfalfa, clover, or soybeans. Larvae were observed as before for evidence of molting, and head capsules were collected. The study showed that virtually all of the larvae on all diets never developed beyond the 2nd instar. Only two larvae, reared on clover, completed development, pupated and emerged as adults. Larvae were also placed on greenhouse-grown, celery plants and field-collected, wild carrot. In both cases, the larvae developed, pupated, and emerged as an adult within 2 days of larvae reared on artificial diet at the same temperature.

The failure of the larvae to fully develop on the bluegrass, clover, soybean, and alfalfa diets could be due to a number of factors including the inability of the young larvae to feed and establish themselves on the coarser foliage of these particular plants. Further investigation is needed to determine if older larvae are capable of feeding and of completing development on these particular host plants.

By *Fredric Miller, Jr.*
Section of Economic Entomology, Extension

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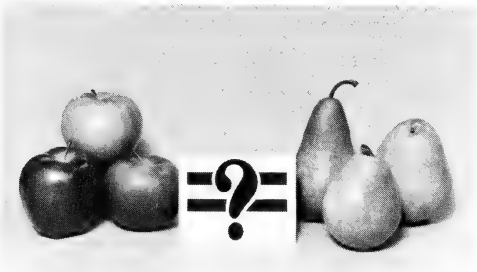
The Illinois
NATURAL HISTORY
NATURAL HISTORY SURVEY REPORTS

MAY 1987, NO. 267

Are Apples Pears?



Anyone can choose the apples or pears in this picture, but a blooming apple tree or a blooming pear tree have many similarities (photo by Molly Hardin Scott)

Are apples pears? This question would never occur to the nonbotanists. After all, pears and apples appear to be very different fruits, with different colors, textures, shapes, flavors, and aromas. On closer examination, however, pears and apples have a lot in common.

Some grocery stores in Illinois now sell "Asian Pears" that are shaped like an apple but with a gritty flesh like a pear. Also, pear and apple trees in flower look much the same. Botanists classify both pears and apples, along with a number of other fruits, such as strawberries, raspberries, blackberries, cherries, plums, peaches, and apricots, to the Rose Family (Rosaceae). This family is subdivided into four subfamilies, and the pear and apple belong to subfamily Maloideae, which is characterized by a particular fruit type called a "pome" with a thin skin covering a fleshy layer and a central cartilaginous or stony core. In addition to pears and apples, hawthorns, cotoneasters, shadbushes, firethorns, mountain-ashes, rowan trees, medular, loquats, chokeberries, Christmas berry, and quinces belong to subfamily Maloideae.

Botanists like to group similar species (kinds) of plants together into a unit of classification called a genus. Thus the genera often used for the above plants are: *Pyrus* (pears), *Malus* (apples), *Crataegus* (hawthorns), *Cotoneaster* (cotoneasters), *Amelanchier* (shadbushes), *Pyracantha* (firethorns), *Sorbus* (mountain-ashes and rowan trees), *Mespilus* (medular), *Eriobotrya (loquats), Aronia* (chokeberries), *Heteromeles* (Christmas berry), *Cydonia* (quince), and *Chaenomeles* (Japanese quinces). In addition, there are about a dozen other genera of Maloideae that are less familiar.

The usage of the genus names just cited are fairly standardized in most current horticultural, gardening, and popular botanical publications. However, there is a great deal of controversy among botanists about the circumscription of genera of Maloideae. There are botanical reasons why as few as 10 genera or as many as 30 could be recognized, depending on how much emphasis should be given to the various similarities and differences. Additionally, very little is known about the relationships between the different groups. For example, are apples more closely related to pears or to mountain ashes?

With funding from the National Science Foundation, Ken R. Robertson, of the Section of Botany and Plant Pathology and his postdoctoral assistant Joseph R. Rohrer, along with James B. Phipps and Paul G. Smith of the University of Western Ontario, London, are studying the problem of how many genera are

best recognized in light of today's knowledge and how they are related to one another. They are examining flowers, fruits, leaves, buds, and other plant parts for over 150 species representing all genera and subdivisions of genera of Maloideae. This information is being recorded as numerical data so that it can be analyzed by computer-aided cladistic and phenetic methods, especially the PAUP (Phylogenetic Analysis Using Parsimony) package developed by David Swofford of the Section of Faunistics and Insect Identification. From this information they will be preparing a modern classification system of subfamiily Maloideae in which the genera are defined in a consistent way and in which relationships are clearly inferred. This research will be of considerable use to botanists, horticulturalists, ecologists, and pomologists by providing a standardized taxonomy.

At present, this project is in the data-gathering stage, but some generalizations are possible. In taxonomic botany courses, students learn that the subfamily is characterized by flowers with the floral parts inserted above the ovary (an inferior ovary). After examining flowers of more than 180 species, it is clear that there is considerable variation in the degree of fusion between the ovary and the hypanthium (floral cup) and between the carpels (individual female parts of the flower) themselves. The ovary is free from, but closely surrounded by, the hypanthium in the anomalous genus *Dichotomanthes*. In other genera the degree of fusion varies. In *Heteromeles* and *Pyracantha* the lower half of the ovary is fused with the hypanthium, while in *Amelanchier*, *Aronia*, *Cotoneaster*, *Docynia*, *Photinia*, and *Stranvaesia* all but the upper quarter of the ovary is fused to the hypanthium. In other genera, notably *Crataegus*, *Malus*, *Pyrus*, and *Sorbus*, the ovary and hypanthium are completely fused together. Fusion of the carpels to each other varies from being fully united in most genera, to partially fused together in *Hesperomeles*, to free in *Cotoneaster*, *Heteromeles*, and *Pyracantha*. Preliminary cladistic analysis of the floral data suggests that evolution in the subfamily has included an increase in fusion between the carpels themselves and between the ovary and the hypanthium, a reduction in the number of carpels, and an increase in the number of ovules per carpel from two to numerous and, independently, a reduction from two to one.

Well, you ask, are apples pears? While a definitive answer is premature, preliminary data indicates that the answer is "no" with apples and pears being similar but clearly separate genera. In fact, they seem to have evolved along separate evolutionary lines with *Malus* being more closely related to *Docynia* (Chinese quince) and *Pyrus* to *Cydonia* (quince).

By *Kenneth R. Robertson and Joseph R. Rohrer*
Section of Botany and Plant Pathology

Eleventh Bird Book Published

The eleventh in a series of publications on the birds of Illinois by Jean Graber, Richard Graber, and Ethelyn Kirk has been published recently by the Survey. Its title is *Illinois Birds: Corvidae*, and it is Biological Notes No. 126.

The crow family in Illinois is represented by the well-known blue jay, the American crow, and the fish crow. The publication also mentions the gray jay, scrub jay, Stellar's jay, Clark's nutcracker, black-billed magpie, and the common raven.

One notable characteristic of the Corvidae is their diurnal migration usually along shorelines and floodplains. When crows are found in forest habitat, the trees and shrubs are usually widely spaced. Food eaten by jays includes nuts, corn, seeds, green shoots, beetles, larvae, and other insects. The jay's propensity to eat eggs and nestlings of other birds has been well documented.

Copies of this recent publication may be obtained by writing to the Chief, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820.

By *Shirley McClellan*
Associate Technical Editor

Landscape Simulation Models Help in Park Planning

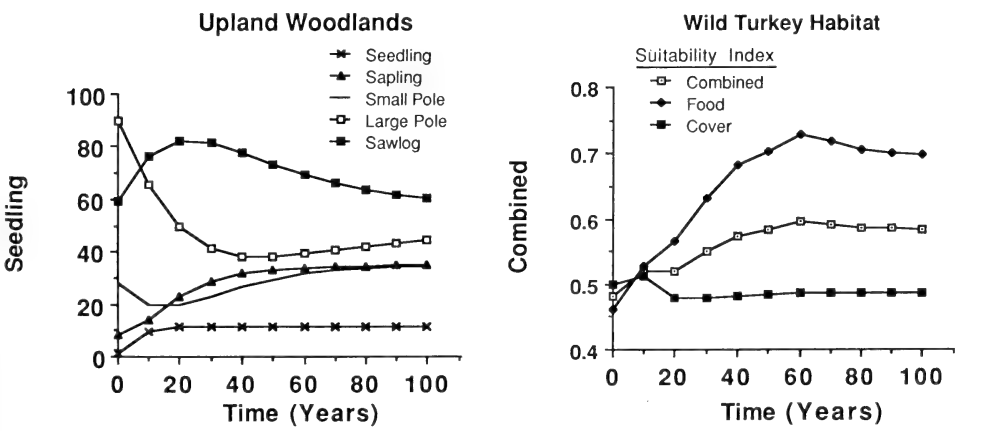
As reported in the November 1986 issue of INHS Reports, woody biomass is an increasingly important part of the current shift toward renewable energy sources. Many parts of Illinois have abundant supplies of woody biomass, but if these supplies are to be wisely used, we need the ability to plan sustainable harvests and predict associated environmental impacts. As part of a larger study of Illinois renewable energy resources sponsored by the Illinois Department of Energy and Natural Resources, Survey ecologist Christopher Burnett has developed a landscape simulation model that schedules sustained-yield woodland harvests and predicts how the harvests would affect wildlife habitat quality.

In cooperation with the Vermilion County Conservation District, the 1650-acre Kennekuk Cove Park in east-central Illinois is being used as a test case for the model. First, all the land in the park was classified into one of 48 cover types on the basis of vegetation or land use, vegetation age, and topography. Starting with the initial cover-type inventory, the model then simulates the "flow of acres" among cover types based on assumptions about rates of natural and managed conversion among the types. Finally, the changing distribution of acreage among cover types is used to project the availability of various resources through time. Future fuelwood volumes are calculated from age-dependent yield tables, and wildlife habitat qualilty is estimated by comparing the projected cover-type proportions with optimal cover-type proportions for the wildlife species of interest.

To run the model, a land-management policy must be specified that sets goals for the amount of each woodland type to harvest and the ages at which the harvests should occur. The management policy can also specify minimum acreage requirements for any of the cover types. Using a cybernetic control structure, the model then schedules the number of acres of each cover type that need to be harvested or otherwise treated in each year of the simulation. A special feature of the model is that for any given policy or initial inventory it schedules management activities so that a steady-state distribution of cover types will eventually be reached. This feature allows the managers to plan a sustained-yield harvest program and see what it will take to achieve it.

As an example, one land-management policy considered for Kennekuk Cove was to harvest upland forests for a combination of timber and fuelwood at age 80 while stabilizing the current proportions of grasslands, shrublands, savannahs, and woodlands. Although this policy maintains the acreage of upland woodlands at its initial value of 186 acres, the distribution of age classes within this type is quite dynamic for several decades. At equilibrium, this policy would produce about 45 cords of fuelwood and 10,000 board feet of timber annually from the harvest of 2.5 acres of 80-year-old woodland.

Because plans are being made to re-



Projections of wooded upland habitats and wild turkey habitat suitability for one possible management policy.

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store wild turkeys to the study area, this species was used to illustrate the prediction of wildlife habitat quality. The wild turkey submodel considers feeding and cover habitats separately and combines them into an overall index. According to the turkey model, the above policy would lead to a slight increase in the overall suitability of the park for wild turkeys. Although the cover index declines as the thick, young stands of today are allowed to reach the 80-year rotation age, the food index increases as the maturing stands produce more acorns, more than compensating for the loss of cover.

So far, six alternative land-management policies for Kennekuk Cove have been simulated and are being compared. The computer results are helping park personnel understand the probable consequences of different management options, but the best choice of alternative futures for the park remains a matter of human judgement.

By *Christopher Burnett*
Section of Wildlife Research

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he Illinois

NATURAL HISTORY SURVEY REPORTS

JUNE 1987 NO 258

Natural Resources Book Ready for Distribution

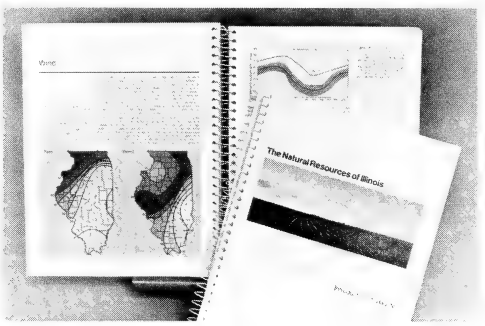
The story of the resources of Illinois is told in a recent publication of the Survey, *The Natural Resources of Illinois: Introduction and Guide*, beautifully designed and illustrated with more than 200 colorful maps, tables, and graphs. Familiar scenes of the Illinois landscape introduce each of the six sections of this 224-page book: General Characteristics, Agriculture, Fish and Wildlife, Climate, Water Resources, and Geological Resources.

Illinois leads the nation in the production of soybeans, is second in the production of corn and hogs, third in commercial bank assets, and fifth in the production of coal. These and hundreds of other facts about the state are found in the new publication from the Illinois Natural History Survey, a division of the Department of Energy and Natural Resources. The book was compiled by the staff of the Survey with contributions from two sister surveys, the State Water Survey and the State Geological Survey, and from specialists across the state.

The bibliography includes over 450 citations and an appendix lists state and federal agencies for those seeking assistance or further information.

"This book is a product of many years of work and will provide both general readers and specialized audiences with fascinating and valuable information," said DENR Director Don Etchison. "A full understanding of our natural resource legacy can lead to better resource management and use for all Illinois citizens."

The Natural Resources of Illinois: Introduction and Guide is available from the Illinois Natural History Survey, Room 172, 607 East Peabody Drive, Champaign, IL 61820. The cost is $10 per copy; out-of-state residents must add the sales tax of their respective states. Checks or money orders should be made payable to the Illinois Natural History Survey.

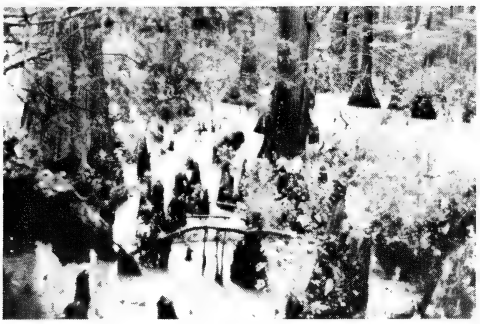


The cover of the Survey's most recent publication presents a photograph of the beautiful farm land in Illinois and inside the cover, many maps and graphs are presented for the reader to study.

Mycology of Cypress Swamps

The cypress swamps of the Cache River Basin in southern Illinois are characterized by soil which is saturated with or covered by water for 12 or fewer months per year, and by the presence of trees, notably cypress, tupelo, and Drummond's red maple. The shrub community consists predominantly of buttonbush, Virginia willow, and swamp rose. During the summer the water surface is covered with mosquito fern, duckweed, frogbit, and the submerged aquatic macrophyte, prickly coontail, occurs abundantly.

These cypress swamps are rich in submerged, decaying wood and leaves which form the primary substrate for



Heron Pond Cypress Swamp, Johnson County, Illinois (photo by J. Leland Crane).

higher fungi in aquatic systems. The mycobiota is influenced by the wide range of physical and chemical parameters in these cypress swamps. These ranges reflect the annual growth, maturation, and death of aquatic macrophytes, the autumnal input of leaf litter, alternating flooding and drying conditions, and seasonal changes in temperature. The extremes in some parameters such as temperature, dissolved oxygen, and water levels affect fungal succession and the alternation of sexual and asexual states in fungi.

Limited evidence exists for the presence of a distinct group of fungi associated solely or primarily with cypress swamps. The number of indigenous species that occur in these swamps is quite high. Of the 147 species reported, two represent new genera known only from cypress swamps in southern Illinois. The mycota from these swamps consists predominantly of dematiaceous and aeroaquatic Hyphomycetes and a variety of Ascomycetes. These swamps contain numerous rare and indigenous fungal species and serve as the type locality for two genera and two species.

By *J. Leland Crane*
Section of Botany
and Plant Pathology

Biologic and Genetic Diversity of Illinois Plants

Illinois, "The Prairie State," has substantial natural resources which provide the basis for the State's long-term development and vitality. Much of the State's economic success is derived from the abundant, black, fertile soil that has resulted from the activity of several thousand years of extensive prairie vegetation.

The development and growth of human civilization over the last century has incurred an irretrievable loss of natural biological habitats and associated reduction in total biological diversity. Very little of the original prairie remains, but fortunately for Illinois citizens, this state was a pioneer in the conservation of natural areas through the Nature Preserves Commission and the State-funded Illinois Natural Areas Inventory. Sweat and funds were invested, research performed, laws passed, and lines drawn on maps creating over 100 refuges and preserves so that organisms could be observed and protected. Since 1963, 58 areas containing remnants of different types of prairies have been formally dedicated as Nature Preserves.

For 128 years Natural History Survey scientists have traveled the State sampling its organisms. Botanists have identified and classified many of them, gathered data on their life histories, and noted their abundance and distribution. All these efforts have contributed to the formation of nature preserves, have aided development of management practices for their conservation, and have yielded a cornucopia of information and scientific knowledge about Illinois' organisms. Survey researchers will continue to survey and catalog the Illinois flora and fauna for many compelling reasons.

One reason for prolonging these efforts is that investigators continue to discover new organisms not previously known to occur in Illinois, or observe organisms in new locales. For example, botanists in the Survey's Section of Botany and Plant Pathology and Section of Faunistic Surveys and Insect Identification over the last 3 years have found and identified new populations of 24 rare or endangered plant species. Some, like the sedge *Carex brunnescens* and the dog-toothed violet *Erythronium mesochoreum*, had never been reported to occur in Illinois. For most of the other discoveries, the species was thought to

Table 1. New plant species or new locations for rare plant species found by Illinois Natural History Survey personnel. An asterisk (*) indicates that the species distribution is limited to three or fewer sites.

Plant	County location	Observer
**Agropyron subsecundum*	Lake	J. Taft & M. Solecki
**Aristolochia serpentaria* var. *hastata*	Johnson	D. Ketzner
**Asclepias lanuginosa*	McHenry	B. McKnight
Aster schreberi	Will	J. Taft & M. Solecki
**Carex brunnescens*	Lake	J. Taft & M. Solecki
**C. intumescens*	Johnson	D. Ketzner
**C. oxylepis*	Johnson	D. Ketzner
**C. physorhyncha*	Union	E. Ulaszek
**C. styloflexa*	Williamson	E. Ulaszek
**Cirsium carolinianum*	Jackson	D. Ketzner
Corallorhiza maculata	Will	J. Taft & M. Solecki
**Corydalis sempervirens*	Ogle	B. McKnight
**Equisetum pratense*	Ogle	B. McKnight
**Erythronium mesochoreum*	Macoupin	K. Robertson
Euonymus americanus	Johnson	D. Ketzner
Galium labradoricum	McHenry	B. McKnight
Hydrastis canadensis	Williamson, Pope, Johnson, Jackson, Union, St. Clair, Massac, Pulaski & Saline	B. McKnight, E. Ulaszek, J. Taft & M. Solecki
Larix laricina	McHenry	B. McKnight
**Lilium superbum*	Williamson	E. Ulaszek
**Lysimachia radicans*	Johnson	D. Ketzner
**Melothria pendula*	Union	D. Ketzner
Panax quinquefolius	Scott, Williamson, Pope, Coles, Clark & Will	B. McKnight, J. Taft E. Ulaszek & M. Solecki
**Paspalum dissectum*	Williamson	E. Ulaszek
Planera aquatica	Johnson, Pulaski	D. Ketzner
**Plantago cordata*	Jackson	D. Ketzner
**Polygonatum pubescens*	DuPage	B. McKnight
**Ptilimnium costatum*	Johnson	D. Ketzner
Quercus phellos	Pulaski	D. Ketzner
**Ribes hirtellum*	Lake	J. Taft & M. Solecki
**Rubus enslenii*	Williamson, Jackson	D. Ketzner & E. Ulaszek
**Silene regia*	Lawrence	E. Ulaszek & M. Solecki
Styrax americana	Pulaski	D. Ketzner
Veratrum woodii	Coles, Cumberland	B. McKnight
Veronica scutellata	Will	J. Taft & M. Solecki
**Viburnum molle*	Pike	J. Taft
**Woodsia ilvensis*	Ogle	B. McKnight

be extirpated because of the time that has elapsed since the species was last collected or reported, or the species was known to occur at only three or fewer sites in the State. As examples, *Paspalum dissectum* was last collected in 1893, and *Corydalis sempervirens* had not been reported in 25 years. New locations have been found for an additional 12 species of threatened plants.

Secondly, a century of surveying and cataloging the State's organisms has produced an historical tapestry to which our current observations can be compared. Such comparisons are priceless because they provide an opportunity to examine the changes that have occurred in the abundance and distribution of our biological resources as a result of altered climate, expanded agricultural production, population growth, and other consequences of people-centered activities.

A third reason for continuing to survey the State's organisms is that a few major taxonomic groups and several minor ones have never been systematically cataloged. There is little knowledge of how their abundance and distribution have changed from presettlement times. Unless time is given to their study now,

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the ability to gauge future change will be lost.

Perhaps the most compelling argument for continuing the Survey's collection efforts is that preservation of biological diversity requires information on every aspect of a species' behavior, its natural history, its biological processes, and its environmental needs. More importantly, the retention of biological diversity requires protection of genetic and ecological diversity as well.

A nucleus of Survey scientists is striving to obtain research funding so that the Natural History Survey can explore the genetic and biological diversity of our native flora, and investigate management options for optimizing its preservation. They are focusing on prairie vegetation because the surviving Illinois prairie remnants may be at risk as a result of their small size and reproductive isolation from one another. Inbreeding reduces genetic diversity.

Genetic variation arises slowly and by chance through mutation. It is maintained by differential survival and reproduction in particular habitats. Once lost, this genetic material cannot be restored. As genetic diversity declines, so does a species' chances for survival, because also diminished is the capacity to adapt to climate changes, habitat alterations, and new forms of human disturbance that the future might hold, or to successfully compete with introduced, weedy species. A number of species are already listed as threatened or endangered and may be suffering severe "genetic stress." With diminished species survival, the potential is lost for new drugs, foods, fibers, biological sources of disease control, and an enhanced quality of life.

By *Anton G. Endress*
Section of Botany
and Plant Pathology

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Two research boats, the "William C. Starrett" and the "Robert E. Richardson" moored side-by-side for christening at Havana (photo by Molly Hardin Scott).

Two Research Boats Christened

Two pontoon work boats were launched in the waters of the Illinois River, Friday, June 12. Jointly owned by the Natural History Survey, the Illinois State Water Survey, and the State Geological Survey, the vessels have been outfitted and will be used as research laboratories in monitoring the Illinois and the Mississippi rivers in studying stream ecology, hydrology, and other scientific subjects.

The "William C. Starrett" was named for a long-time resident of Havana, a Survey biologist who made many contributions to the scientific knowledge of the Illinois River. He died in 1972. His widow, Mrs. Irene Starrett, christened the boat in his honor. Mrs. Esther Bellrose christened the second boat, the "Robert E.Richardson," in honor of an early investigator at the Survey.

Dr. Frank Bellrose told the assembled researchers from a number of state

and federal agencies about the contributions of these two men, Dr. Richardson in the 1920's and Dr. Starrett in the 1950's and 1960's. He documented the increasing pollution of the Illinois River valley and warned of the losses of fish and waterfowl that will continue to occur.

A demonstration of the boats' capabilities was given on the Illinois River following the christenings. Their electronic equipment was used to search for radio-tagged catfish released in the river earlier. Four of the tagged fish were found about five miles above Havana.

A transmitter, about the size of a human thumb, is surgically placed in the fish's abdomen. After the fish is released, the transmitter's signal is monitored by radio receivers aboard the boats.

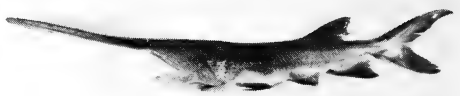
Dr. Richard Sparks, aquatic biologist, told the audience that the boats would permit research that would be impossible otherwise. Scientists will be able to live and and work on board and do long-term observations and experiments.

The "William C. Starrett" is 42 feet long and equipped with a computer system and a variety of monitoring devices. It will be docked at Havana. The "Robert E. Richardson," the smaller of the two boats, is 35 feet long. Home port for it will be Pool 19 on the Mississippi River near Keokuk, Iowa. Build Illinois funds were used to purchase both vessels.

New Interest in the Paddlefish

The giant (up to 125 pounds) primitive and strange-looking paddlefish, or spoonbill cat, was once abundant in the large rivers of Illinois. Overharvest, construction of locks and dams on major rivers, and drainage of floodplain lakes decimated their populations.

Now there is new interest in this fish. Its roe, like that of its near relative, the sturgeon, makes excellent caviar. Since the source of caviar from the Caspian Sea has been cut off on account of the Iranian conflicts and the Chernobyl nuclear accident which contaminated eastern European sturgeon populations, American fishermen have been seeking out the remaining populations of paddlefish to harvest the eggs from



The paddlefish is once again studied as a desirable fish in Illinois waters (photo by Molly Hardin Scott).

nearly "ripe" females. This harvest is further reducing paddlefish populations, but new efforts are being made to supplement natural reproduction with hatchery rearing and stocking of young fish. Another revived interest in the species is for its white, boneless flesh. After removal of the large rostrum, it is marketed as boneless catfish. Paddlefish grow very rapidly and can be raised in ponds and lakes with channel catfish or other cultured fishes.

To gain a better understanding of the biology of the paddlefish, R. Weldon Larimore has been studying its daily and seasonal activity patterns in a small lake in Vermilion County. Small radio transmitters were inserted into the body cavity of the fish and then its activity recorded. During both summer and winter, day and night, this fish moves continuously. It cruises in lazy circles in the lake, moving at less than 0.5 m/s. The paddlefish swims slowly with its large mouth open, feeding on zooplankton. Larimore and his associate, Michael Wiley, are studying the oxygen uptake of the paddlefish in the laboratory to determine if it swims continuously to feed or maintain proper ventilation of its gills, such as has been observed with various species of sharks...

By *R. Weldon Larimore, Section of Aquatic Biology*

Indiana Bats Are Illinois Bats Too

Bats, among the world's most fascinating and beneficial animals, remain perhaps the most misunderstood and persecuted group. Movie producers and sensational journalists portray bats as blood-sucking, disease-ridden demons. Quite to the contrary, bats have proved invaluable in the development of new drugs (e.g. blood pressure medication, vaccines), and in studies of disease resist-

ance, speech pathology, and aging and healing processes. Studies of the remarkable delayed fertilization of some bats have provided new findings in artificial insemination and birth-control methods. Studies of bat sonar have led to the development of navigational devices for the blind and sonar used in military defense.

Illinois has 12 native species of bats; about 40 species of bats are found in the continental United States and nearly 1,000 species worldwide. Illinois bats range in size from the ⅕-ounce eastern pipistrelle (*Pipistrellus subflavus*) to the 1½-ounce hoary bat (*Lasiurus cinereus*) with a wing span of up to 16 inches. The most commonly encountered Illinois bats include the little brown bat (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*) which can be seen feeding around street lamps on summer evenings.

The most rarely seen bat in Illinois is the big-eared bat (*Plecotus rafinesquei*), with ears over 1¼ inches long. Of the world's 1,000 species of bats, only three species feed on blood and more than 700 species feed on insects. All Illinois bats are insectivorous. In fact, the little brown bat can devour over 140 mosquitoes in less than 15 minutes and up to 900 insects within an hour (including harmful corn borer and cutworm moths).

Although all species of bats in Illinois are protected by law, the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*) are classified as state endangered species by the Illinois Endangered Species Protection Board, and federally endangered by the US Fish and Wildlife Service (US Department of the Interior). Illinois' most recent effort in the conservation of these species includes a cooperative research project between the Illinois Natural History Survey, the Illinois Department of Conservation, and the Illinois Department of Transportation. Other cooperators include the Fish and Wildlife Service (USDI), Indiana/Gray Bat Recovery Team, and the Missouri Department of Conservation.

The Indiana bat is tracked by a tiny transmitter half the size of a dime which is glued to its back (photo by James E. Gardner).

First described from Indiana in 1928, the Indiana bat not only inhabits Illinois, but occurs from Ohio to Wisconsin, Iowa, Oklahoma southeast to northern Florida, and north to Vermont. Once numbering in the millions, continually declining populations now totaling less than 230,000 are protected in the few major caves where they hibernate (called hibernacula). However, from mid-April through mid-September, adult female bats leave their hibernacula and form small maternity colonies (less than 100 bats) beneath the loose bark of dead trees, where they bear and raise their single young.

The first colonies of Indiana bats found in Illinois were discovered by Jim Garner (IDOC), and Joyce Hofmann and Gene Gardner (INHS) in 1986; they were found in a dead northern red oak and a dead cottonwood both located near a permanent stream in west-central Illinois.

Research for the summer of 1987 included an unprecedented radiotelemetry study of the Indiana bats found in this area. Transmitters, half the size of a dime and weighing less than 0.03 ounces, were glued onto the bats, allowing them to be followed with antennas and tracking receivers. These techniques provided information on home range size, habitat utilization, and selection of roost trees. This critically needed information should allow accurate assessments of potential environmental impacts caused by disturbance or destruction of suitable summer habitat, thus providing some protection to maternity populations of Illinois' Indiana bats.....

By *James E. Gardner and Joyce E. Hofmann, Section of Faunistic Surveys and Insect Identification*

The Illinois

NATURAL HISTORY SURVEY

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An Update on INRIS

During the past year, a computerized information system has been developed and its coverage expanded by several Illinois state agencies to allow the people of Illinois; scientists, Federal, State, and local agencies; educational institutions; libraries; businesses; and nature and environmental groups, access to Illinois natural resources information.

The Illinois Natural Resources Information System (INRIS) is a joint project of the Illinois Natural History Survey, the Illinois State Geological Survey, the Illinois State Water Survey, the Illinois State Museum, and the Hazardous Waste Research and Information Center of the Department of Energy and Natural Resources (DENR). Various other State, Federal, and University of Illinois agencies are also participating.

INRIS provides a framework through which users may access many on-line "products" of the Surveys and affiliated agencies. Such products include interactive simulation models, scientific reports, searchable databases and bibliographies, environmental data sets, and collections dealing with the natural resources of Illinois. The INRIS staff will be continuing to add new products as the system develops further. To use INRIS, users need either a personal computer (PC) with communications software and a modem, or a computer terminal and a modem. INRIS includes on-line help screens for each product.

An INRIS user can choose a particular product from a series of menus. If the product chosen is a simulation model, it prompts the user for the required data. The user can choose to view output on the terminal or the PC screen, transfer it into a file on the PC or print it at the PC printer. After an initial period of free usage, users will be charged for using INRIS. A toll-free phone is available statewide for INRIS access.

Additional INRIS product contributors continue to be sought. Those who would like more information or are interested in using or in contributing to INRIS are encouraged to contact the INRIS Director, Mark McReynolds.

By *Mark McReynolds, Section of Economic Entomology.*

September 1987 No. 269 Published monthly except in July and August by the Natural History Survey, a division of the Illinois Department of Energy and Natural Resources operating under the Board of Natural Resources and Conservation

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NATURAL HISTORY SURVEY REPORTS

Pesticides and Pest Management

Because the Illinois Department of Energy and Natural Resources has organized a conference for November 12–13 entitled "Pesticides and Pest Management," this issue of *Illinois Natural History Survey Reports* is being dedicated to pesticide-related programs of the Survey. The conference will be held at the Sheraton International Hotel near Chicago O'Hare Airport. Registration materials and more information can be obtained from Elliott Zimmermann or Linda Vogt, Department of Energy and Natural Resources, 325 West Adams Street, Springfield, Illinois 62706. Telephone: 217-785-3493.

Survey entomologists study insect biology, behavior, ecology and taxonomy; insect/plant interactions; biological and chemical control; and the fate of pesticides in the environment. During the past year, they have discovered new information about many insect pests, including the potato leafhopper, pine sawyer, European corn borer, northern corn rootworm, western corn rootworm, and horn fly. They are also learning how soybean insects recognize their host plant and how beetles, leafhoppers, and aphids transmit plant diseases caused by nematodes, spiroplasma, and viruses. In addition Survey entomologists are searching for nonchemical control alternatives, including insect pathogens, host plant resistance, parasitoids, and cultural practices. They also strive to develop safe and efficient integrated pest management programs by combining existing technology with new discoveries.

The Natural History Survey maintains a comprehensive program in insect pest management including research and service in insect identification, sampling methods, control techniques, pest biology, economic thresholds, and information delivery. A brief overview of our pesticide-related programs follows.

By *William G. Ruesink, Head, Section of Economic Entomology*

IPM, Pesticides, and Extension Education Programs

Illinois agriculture suffers losses of about $500 million a year from weeds, diseases, nematodes, and insects. These losses occur because pest outbreaks are not detected soon enough or because control measures are inadequate. Some producers suffer losses by applying pesticides that actually cost more than damage caused by the pest. To a producer, these pest-related losses can mean the difference between profit and loss.

Currently, many farmers rely on pesticides to reduce or eliminate pest damage. To insure against pest damage, producers sometimes apply pesticides without being certain that a pest problem exists. Unfortunately, these "insurance" treatments of pesticides have created problems of pest resistance, environmental contamination, and a public concern about health risks because of exposure to pesticides. That's the bad news.

The good news is that many farmers are changing their pest control tactics. In the past 15 years, farmers, advisers, and pesticide manufacturers have witnessed the evolution of a concept called INTEGRATED PEST MANAGEMENT (IPM). Without question, economics of

pest control and environmental concerns about pesticides have sparked an interest in IPM.

What is IPM? IPM is a "common sense" approach that takes the guesswork out of managing and controlling pests. IPM is based on four strategies.

l) Crop pest scouting–timely field visits to identify and assess the density of the pest.

2) Using economic threshold–simply the number of pests that can be tolerated before control is needed. In other words, if the pest isn't there, or at high enough levels, don't try to kill it.

3) Chemical and biological control–pesticides aren't applied until the pest population has reached the economic threshold; beneficial insects are thus favored through judicious use of pesticides.

4) Cultural management–simple as they may seem, crop rotation and resistant crop varieties are important factors in preventing pest outbreaks without using pesticides.

County, area, and state staff of the Cooperative Extension Service (CES), University of Illinois, play a key role in the dissemination of information about pest management.

They have developed printed materials that deal with the biology, identification, economic thresholds, and control of key crop pests. Annual IPM programs conducted by the CES staff, in cooperation with the INHS staff, include the Crop Protection Workshop, Scout Training Schools, Field Workshops, and a weekly Insect, Weed, and Plant Disease Survey newsletter.

Is IPM being adopted by Illinois farmers? The answer is a resounding "yes." Crop scouting, a key component of IPM, is practiced on 60 percent of the corn and soybean acreage, based on a survey taken in l985. Without question, Illinois farmers are recognizing that IPM, particularly crop scouting, is a risk-reducing program. IPM helps take the guesswork out of managing pests, saving money, and reducing the environmental impact of pesticides.

By *Donald E. Kuhlman, Section of Economic Entomology, Extension*

Insecticide Evaluation Program: Field and Forage Crops

In 1985 the Survey reorganized and expanded its insecticide evaluation research efforts. The program is coordinated by a research biologist who works with Extension Entomology specialists at the University of Illinois and with other Survey scientists.

The major objective of this research is to provide unbiased evaluations and comparisons of insecticide products. The results are reported annually to clientele in lllinois and throughout the nation. Observations on calibration, mixing, application methods for different products, and safety precautions are important portions of the project's annual report.

Research conducted from 1985 through 1987 has been directed primarily to the evaluation of products and application techniques used for the control of the major insect pests of corn and alfalfa. Between 4 and 5 million acres of "continuous" corn in Illinois are treated annually with a planting-time insecticide

Researchers evaluate corn root systems extracted from plots treated with biological "insecticides" to control rootworms (photo by Molly Hardin Scott).

to control rootworms (*Diabrotica* spp.). Evaluations have been made throughout the state with both registered and experimental insecticides and with two biological "insecticides," *Beauveria bassiana*, a fungus, and *Steinernema feltiae*, an entomogenous nematode. Other studies have focused on control strategies for the black cutworm (*Agrotis ipsilon*) and for the first and second generations of the European corn borer (*Ostrinia nubilalis*).

Researchers also have evaluated insecticides applied for control of the potato leafhopper (*Empoasca fabae*) and the alfalfa weevil (*Hypera postica*), the two most significant pests of alfalfa in Illinois. Observers have assessed not only the mortality of the pest species, but also the insecticides' impact on predators and parasites that help hold pest populations below economic levels in alfalfa fields. Reduced application rates of insecticides that control pests without harming beneficial insect populations have been studied also.

Most of the evaluations carried out in this project have been conducted under conditions similar to those confronting Illinois producers. In order to establish large-scale field trials, investigators have cooperated with farmers, aerial applicators, industry representatives, Extension IPM advisers, and University of Illinois Agronomy Research Centers.

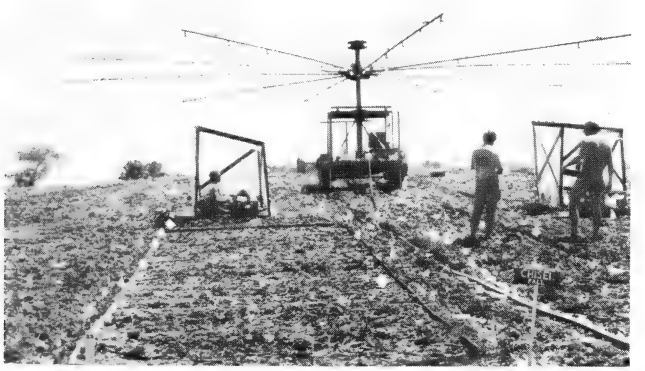
Insecticides are important components in current crop production systems. The insecticide evaluation program provides up-to-date information on insecticides and application techniques. The data help producers select and use appropriate insecticides so that crops can be grown economically and with a minimum level of adverse effects to human safety and the environment.

By *Karl Kinney and Kevin Steffey, Section of Economic Entomology, Extension.*

Chemistry of Pesticides Affects Crop and Environmental Protection

Although the benefits of pesticides for protecting crop yields are generally recognized, pesticide contamination of our environment is a controversial issue partly because potential adverse effects are not easily predicted. The nature of pesticide use in Illinois can exacerbate contamination of nonagricultural ecosystems. First, nearly all cropland in Illinois is treated with a pesticide. Second, most pesticides are applied directly to the soil in early spring to control expected infestations of weeds or insects. Timing of pesticide application coincides with bare soil, heavy rainfall, and relatively cool temperatures. These factors tend to increase the washoff of pesticides into streams, which can result in adverse environmental effects such as fish kills. In Illinois low levels of pesticides are frequently detected in surface water, but very rarely in drinking water. Leaching of pesticides to groundwater has occurred in some states where sandy soils are irrigated.

When pesticides are applied early in the growing season and long before the pests are actually present, a problem separate from that of environmental contamination can occur. The pesticide may not persist at lethal concentrations long enough to kill the pest when it ap-



Rainfall simulator used in soil erosion and pesticide runoff studies was designed and made by the University of Illinois Agriculture Engineering Department. It makes artificial rain for separate plots (photo by Allan Felsot).

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pears in the crop. In some cases microorganisms in the soil have adapted to the presence of the pesticide and break it down so quickly that no pesticide is present when the pest outbreak occurs.

The paradoxical problems of low levels of long-lived pesticide residues contaminating the environment and pesticides breaking down too quickly to control the target pest are being studied in the Survey's Pesticide Chemistry and Toxicology Laboratory. Allan Felsot and Kudjo Dzantor are studying the environmental chemistry of pesticides and hoping that principles discovered can be used to improve both environmental protection and crop protection. They are especially interested in the ability of microorganisms to use a pesticide as an energy or nutrient source. Such microorganisms are called pesticide degraders, and their populations increase in response to addition of the chemical. The Hazardous Waste Research and Information Center is currently funding Felsot and Dzantor to determine if microorganisms can be exploited to clean up pesticide wastes.

In other studies, Felsot is cooperating with J. Kent Mitchell from the University of Illinois Department of Agricultural Engineering to determine the best management practices for reducing runoff of pesticides from cropland. They have determined that no-tillage, cover crops and contouring significantly reduce surface movement of pesticides. In another project, Felsot is working with Don Roseboom, from the State Water Survey to determine the seasonal dynamics of pesticide loading in the Court Creek Watershed.

Environmental studies of pesticide behavior can complement ongoing research on integrated pest management strategies for reducing use of pesticides and for improving the efficiency with which they are used.

By *Allan S. Felsot, Section of Economic Entomology*

October 1987. No. 270. Published monthly except in July and August by the Natural History Survey, a division of the Illinois Department of Energy and Natural Resources, operating under the Board of Natural Resources and Conservation.
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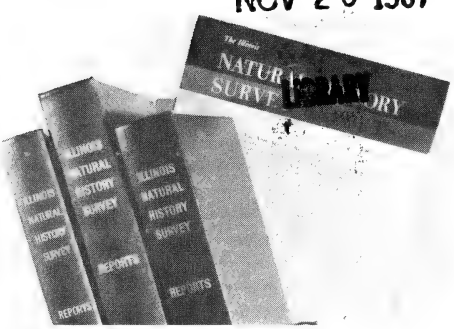


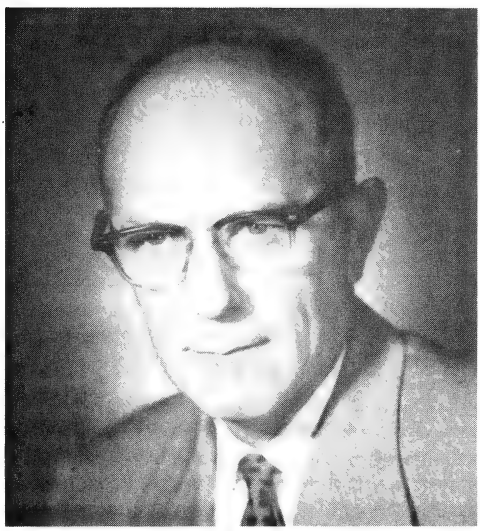
The first issue of the Illinois Natural History Survey Reports pictured with what has grown to fill three bound volumes.

Happy 25th Birthday, Survey Reports!

Illinois Natural History Survey Reports was first published 25 years ago in November 1962 when Acting Chief H. H. Ross had the idea for a Survey monthly newsletter. The first newsletter was an experiment; there were no columns and copy spread across the page from one margin to the other and the heads for articles were cut into the beginning of the opening paragraphs. There were six very short articles and no pictures.

By the second edition, the pages were two column and bold-face heads appeared at the top of each story. In January 1963, pictures were added to the publication. By March, the format was established and there has been little change since in the color of the masthead. Beginning this year, typesetting is being done on the Mergenthaler in the Survey's editorial office. Another change, from letterpress to photo-offset printing, has speeded up publication and produced a more attractive finished product.

Twenty-five years ago, the first issue contained six articles: *One Hundred and Four Years Ago*, H. H. Ross; *Honkertime Again*, Harold Hanson; *The Japanese Beetle*, George Decker and W. H. Luckman; *Suffer from the Common Cold*, John P. Kramer; *The Cock Pheasant Harvest*, T. G. Scott; and *Elm Disease*, E. B. Himelick, Walter Hartstirn, R. D. Neely, and L. L. English.



H. H. Ross

Ross edited the newsletter until September 1968 and retired from the Survey in 1969 after 40 years of service. Wallace LaBerge, insect taxonomist, and Don Schoeneweiss, plant pathologist, assumed the editing duties, alternating as editor every month. In 1973, the decision was made to abandon the 12-month schedule and issue only 10 months of the year, September through June.

Schoeneweiss edited his last copy in 1974 and Robert Zewadski, Survey technical editor, took his place. In October 1980, LaBerge was replaced by George Godfrey, associate insect taxonomist.

Godfrey and Zewadski continued to produce the newsletter until June 1982 when Shirley McClellan, associate technical editor, was appointed sole editor by Chief Paul Risser.

Articles are prepared by scientists in the five sections of the Survey: Aquatic Biology, Botany and Plant Pathology, Economic Entomology (sometimes from the Extension Unit housed in the Natural Resources Building), Faunistic Surveys and Insect Identification, and Wildlife Research. Researchers select their own topics and submit their copy for approval by the Section Head, who then transmits it to the editor, who attempts (with the approval of the authors) to present the information in a style and a language understandable to scientist and layperson alike.

Sometimes called the "green demon," Survey Reports is printed by the University Printing Division. One of its makeup men, Norman Mercer, remembers helping to page those early issues a quarter of a century ago. Now he does most of the paste-up and feels that the publication belongs partly to him.

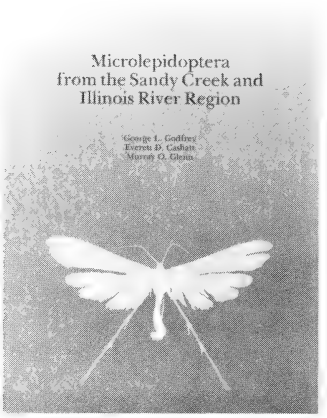
Currently 5,000 subscribers to the *Illinois Natural History Survey Reports*, seem to share Mercer's feeling. We are grateful to all these friends of the Survey.

Recent Publications of the Survey

Neely, D., and E. B. Himelick. 1987. Fertilizing and watering trees. Circular 56. Illinois Natural History Survey, Champaign. 24 p.

This publication is a revised edition of Circular 52, which bears the same title. Circular 52 was first published in 1966 and was reprinted in 1968 and 1972. This popular publication discusses the Hows, Whats, Whys, Whens, and Wheres of fertilizing and watering trees. It also discusses how much fertilizing and watering for trees.

The report is of special interest to homeowners and smaller businesses, villages, and park districts that care for their trees without benefit of professional assistance.



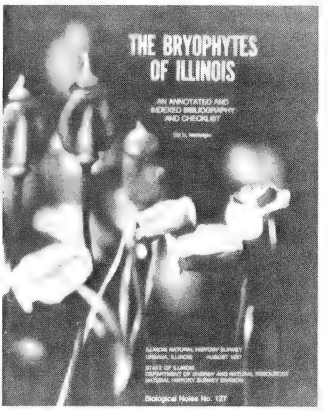
Godfrey, G. L., E. D. Cashett, and M. O. Glenn. 1987. Microlepidoptera from the Sandy Creek and Illinois River Region: an annotated checklist of the sub- orders Dacnonypha, and Ditrysia (in part) (Insects). Illinois Natural History Survey Special Publication 7. 44 p.

The late Murray O. Glenn of Henry, Illinois, collected some 30,000 microlepidoptera representing 954 species between 1927 and 1976 in Marshall and Putnam counties. He donated this collection to the Illinois Natural History in 1977. This collection perhaps represents the most significant assemblage of this group of animals in existence.

Microlepidoptera is a general term that usually includes small moths with wing spans of about 5–25 mm. Macrolepidoptera is the companion term for larger species of lepidoptera. The microlepidoptera have a variety of feeding habits, which include leaf mining, tieing, and rolling; gall making; and stem, root, and wood boring. Some kinds feed on or in fruits, whereas others feed on dead plant or animal matter. Some of the economically important species feed on

grain, parsnips, clothes, flour, and meal, and others include such species as the peach tree borer, spruce budworm, codling moth, grass webworm, and European corn borer.

This publication is primarily a checklist intended for use by the research specialist.



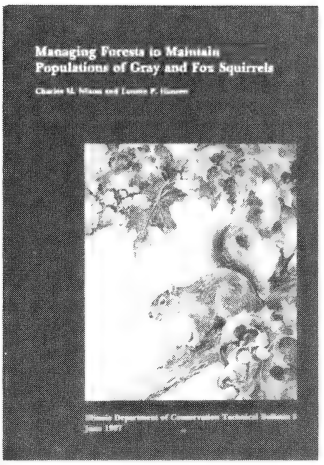
McKnight, Bill N. 1987. The bryophytes of Illinois: an annotated and indexed bibliography and checklist. Illinois Natural History Survey Biological Notes No. 127. 41 p.

Bryophytes are a division of the plant kingdom that contain the liverworts, mosses, hornworts, and sphagna. This report states that "There have been at least 391 other publications relating to Illinois bryophytes...yet the state bryoflora remains poorly catalogued and studied...." This publication is an index of 396 articles dealing with the Illinois bryophytes and a checklist of these plants reported from Illinois. The publication also includes an Author Index, Chronological Index, County Index, Region Index, and Subject Indices.

This report is intended for use by research specialists and will not be of general interest to laypersons.

Nixon, C. M., and L. P. Hansen. 1987. Managing forests to maintain populations of gray and fox squirrels. Illinois Department of Conservation Technical Bulletin 5. Springfield. 35 p.

This bulletin was published by the Illinois Department of Conservation. It was written by scientists at the Natural History Survey, and edited, composed,



and designed by personnel in the editorial section of the Natural History Survey. The research on which this publication is based was supported (in part) by Federal Aid in Wildlife Restoration Project W-66-R through the Illinois Department of Conservation.

This report will interest wildlife biologists and managers, foresters, landowners, and sportsmen and was designed as a management guide "to maintain populations of fox and gray squirrels...in the forests of Illinois and adjacent states, an area that includes the western portion of the central hardwood forest region of the Ohio and middle Mississippi river valleys. It is intended for managers of public forests and for those who provide technical assistance to the owners of private forests."

Single copies of all the above publications are available without charge upon request. Requests for multiple copies should be made in writing and should explain the use to be made of the publication. Address correspondence to:

Office of the Chief
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Neely, R. D., and C. G. Heister, compilers. 1987. The natural resources of Illinois: introduction and guide. Illinois Natural History Survey Special Publication 6. 224 p.

This unique publication was prepared by more than 50 specialists of the

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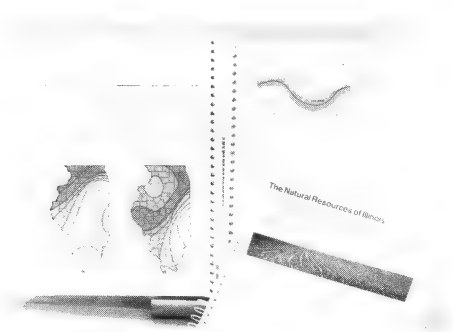
Illinois Natural History Survey, State Geological Survey, State Water Survey, Illinois Department of Conservation, and the University of Illinois. This book is a handy reference to Illinois' many and varied resources. There are nearly 100 separate headings; more than 200 maps, tables, and other graphics in color; and a bibliography of over 400 citations. General subjects included are GENERAL CHARACTERISTICS OF ILLINOIS, AGRICULTURE, FISH AND WILDLIFE, CLIMATE, WATER RESOURCES, and GEOLOGICAL RESOURCES. This book will be of special interest to school and university libraries for reference and to students, resource planners, government officials at all levels, farmers, sportsmen, and anyone who has a professional or personal interest in Illinois' natural resources.



Copies of *The Natural Resources of Illinois: Introduction and Guide* may be purchased for $10.00 each from:

Illinois Natural History Survey
607 East Peabody Drive
Champaign, Illinois 61820

Checks or money orders should be made payable to The Illinois Natural History Survey.

By *Glen Sanderson,*
Chairman, Publications Committee

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Phyllophaga

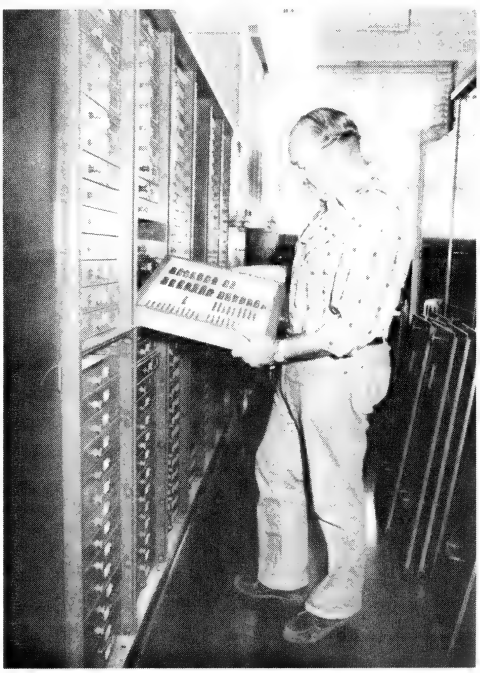
The Illinois Natural History Survey collection of May and June beetles, the genus *Phyllophaga*, is the best in the world. Historically, three outstanding specialists contributed to the development of this fine collection with their expertise and their publications. Because of the economic importance of the June bugs and their larvae (white grubs or grub worms) it was recognized very early that the various species had different habits, hosts, and seasonal appearance.

Because of these differences, it is essential to identify the species precisely. It was discovered in the late 1800's that the sexual characters (the genitalia) were very diagnostic, even when the species were externally nearly identical. This breakthrough aided in the precise identification of the more than 200 kinds in the United States. Although some new or undescribed species are known from our fauna, most of our species are now named.

Circumstances are different in Mexico, Central America, South America, and the West Indies, where as high as 50 percent of the species may be unknown. Specimens of many of these undescribed species reside in the Illinois Natural History Survey collections because of the most recent devotee, Dr. Milton W. Sanderson. Specializing on the June bugs very early, his research at the Survey was done from 1942 to 1975, but his work continued after retirement, until 1987.

Prior to Sanderson, the Illinois specialists were Dr. Stephen A. Forbes and one of his students, Dr. Robert D. Glasgow. Forbes' first paper in 1891, "On the common white grubs, *Lachnosterna* and *Cyclocephala*," was in the *Report of the Illinois State Entomologist* (Vol. 17, p. 30–50). His work culminated in 1916 with "A general survey of the May beetles (*Phyllophaga*) of Illinois," as Bulletin 186 of the Illinois Agriculture Experiment Station.

His student, Robert D. Glasgow, took over at that time and published a significant paper in 1916, establishing the basic synonymy (based on examination of genitalia of the types) which we still use today. Although he described only a few new species, one of these (*forbesi*)



Dr. Robert E. Woodruff, Florida entomologist, examines specimens in the Survey insect collection.

was named in honor of his mentor. It is one of the abundant species in Illinois and causes economic damage periodically. Unfortunately, much of Glasgow's work was never published and his notes have not been located.

Milt Sanderson was an avid enthusiast of the group, publishing his first paper on them in 1936 and continuing to publish through 1965. Much of his work remains unpublished, but his collections and detailed notes will enable others to continue the process of naming the new species and further enhancing our knowledge of these dominant members of our insect fauna.

Because of a long friendship, as well as a professional association, when Milt decided to culminate his career on these beetles, he turned over the notes, drawings, and specimens (and the responsibility to continue the tradition) to Robert E. Woodruff, an entomologist employed by the Florida Department of Agriculture. As part of his work on the Scarab beetles of Florida, he will publish the May beetles of Florida in the next year, treating 55 species. Following that, the fauna of the Caribbean, Central America, and the U.S. will be studied.

Because of the rich traditions and extensive collections at the Survey, it will always be a center for the study of these insects. In order to curate these collections and to support their study, the Survey has invited Dr. Woodruff to Urbana for a total of two months (September 1987 and April 1988). This will place the material in good order before it is incorporated into the new collection compactor system which will be initiated next year. Dr. Woodruff's visits are being funded by a grant in support of the insect collections of the Illinois Natural History Survey (NSF BSR84–11418).

By *Dr. Robert Woodruff, Entomologist, Florida Department of Agriculture*

Winter Populations of Bald Eagles in Illinois

The bald eagle is among the largest birds of North America. The average body length is 34 to 43 inches and wingspan is generally 6 to 7 feet. Female bald eagles are generally larger and heavier than males; average weights of females range between 10 and 14 pounds compared with weights for males between 8 and 9 pounds.

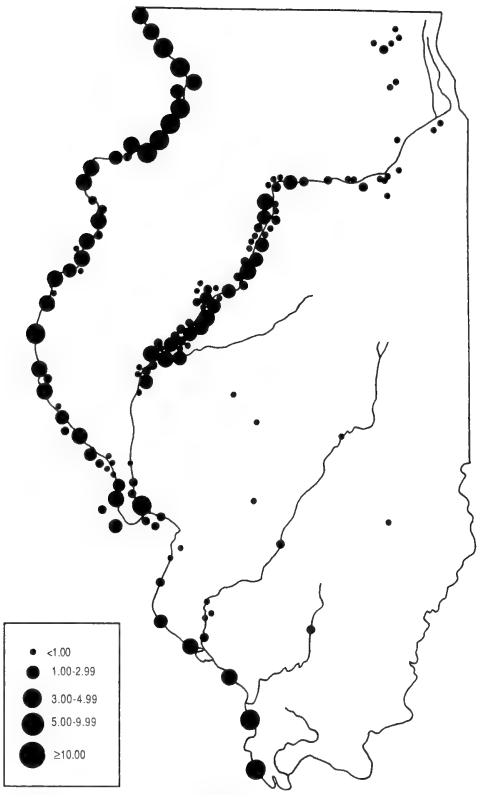
Immature and subadult plumages of bald eagles are mostly dark brown with irregular patches of white on the underside of the wings or elsewhere on the body. At 4 to 5 years of age, bald eagles attain the familiar adult plumage, which is a dark brown body with pure white head and tail. Bald eagles feed primarily on fish.

The bald eagle is the only sea or fishing eagle that inhabits North America. Seven additional members of this genus occur in other parts of the world.

In recent years, the numbers of bald eagles in North America have rebounded from the critically low levels that resulted from loss of habitat, illegal shooting, and the widespread use of certain persistent pesticides. A reasonable estimate of the midwinter population of bald eagles for the lower 48 states in the early 1980's was 14,000–22,000 birds. The 1985 estimate of the breeding population of bald eagles in the United States was approximately 5,000 pairs; about 1,770 pairs nest in the conterminous 48 states and the remainder in Alaska. Only some 500 pairs nested in the lower 48 states in the early 1960's.

Historically, the bottomlands near the confluences of the Missouri, Ohio, and Mississippi rivers were major nest areas for bald eagles, and the large rivers and wetlands in and adjoining Illinois served as important winter habitat. Because of human impacts on eagles and their habitats, small numbers of eagles were observed in Illinois from the late 1800's until about the mid-1900's. Currently, however, the Mississippi River valley from southern Minnesota to southern Illinois is once again an important winter area for bald eagles. Illinois, Missouri, and Arkansas host several hundred bald eagles each winter.

In the late 1950's, the decline in eagle populations stimulated interest in monitoring the numbers of eagles found along the Illinois and Mississippi rivers in January. Aerial surveys of migratory waterfowl conducted by the Illinois Nat-



Mean number of bald eagles counted per aerial inventory at areas censused, 1972–1986.

ural History Survey provided the means to monitor bald eagle populations in the floodplains of the Mississippi and Illinois rivers. The total eagles counted in January ranged from 63 in 1960 to 1,217 in 1986. A majority of eagles seen during this winter inventory was associated with the Mississippi River floodplain. Since 1973, numbers of eagles censused in January along the Illinois River usually ranged between 100 and 300 with a maximum of 383 observed in 1986.

In 1972, the aerial inventories of eagles were expanded to include a longer period, October through April, and areas were added outside the Mississippi and Illinois floodplains. Some areas were censused for more years than others, from 1972 through 1986, but the figure depicts the distribution of the average number of eagles seen per inventory flight on all areas censused in Illinois. Eagles generally appeared in early to mid-October in the northern and central regions of Illinois and in late October in the southern regions. Eagles usually departed Illinois by mid-April.

The Illinois and Mississippi river floodplains hosted a majority of bald eagles in winter in the state. The mean number of eagles seen per inventory was highest for the upper Mississippi River region north of Rock Island, with values that ranged from 4.1 to 20.9 eagles per flight on the various areas censused. Six of the 11 areas censused in the upper Mississippi River region had an average of more than 10 bald eagles per inventory. By comparison, only four areas in the other regions censused throughout Illinois (the Keokuk, Iowa, to Meyer, Illinois; Grand Tower, Illinois, to Cape Girardeau, Missouri, to Cairo, Illinois, stretches of the Mississippi River and the Flat and Swan lakes area near the confluence of the Illinois and Mississippi rivers) had values that exceeded 10.0 for the mean number of eagles per inventory. Low numbers of bald eagles were observed in the surface-mined lakes region in west-central Illinois, the northeast lakes region, the reservoirs and cooling lakes in the central and southern region, and the lower Kaskaskia River region. Intensified enforcement of laws protecting bald eagles, the protection and management of habitats identified major areas where eagles feed, roost, and loaf, and the reduction of the availability of lead shot to eagles should result in an increase in the number of bald eagles that winter in Illinois.

By *Stephen P. Havera, Section of Wildlife Research*

Land Use/Cover and Stream Water Quality

During the past two decades, economic and physical resources have been devoted to restoring and protecting lakes and streams in the United States. Initially, water quality protection and restoration programs, as mandated by the Clean Water Act, concentrated on controlling point-source inputs. However, water quality standards were not being achieved in many regions because of non-point sources of pollution. Recently, federal and state environmental agencies have emphasized techniques

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and policies to control non-point source pollution. In the Midwest, most efforts have been directed toward controlling agricultural runoff.

Lewis L. Osborne, Michael J. Wiley, and R. Weldon Larimore of the Aquatic Biology Section recently completed a study of the relationship between land use and concentrations of phosphorus and nitrogen in the 500-square-mile watershed of the Salt Fork, a major tributary of the Vermilion River, in east-central Illinois. The watershed encompasses Urbana-Champaign, Rantoul, St. Joseph, Oakwood, and Sidney; each discharges municipal effluents into the river.

The three investigators sampled water chemistry biweekly at 22 stations in the Salt Fork from December 1983 through December 1984. Land use and vegetative cover patterns were determined by interpreting false-colored infrared aerial photographs that were then digitized on the PRIME 750 computer using ARC/INFO, a geographic information system. Land use and cover data were related to the mean seasonal concentrations of nitrate-nitrogen and soluble reactive phosphorus using multiple regression analysis.

The researchers found high concentrations of nitrate and phosphorus that reflected the eutrophic nature of the Salt Fork watershed. Phosphorus concentrations generally increased from headwaters to downstream reaches, suggesting that there is nutrient "loading" in the river. Phosphorus concentrations were always higher downstream of urban centers. Unlike previous reports of the adverse effects of agricultural activity on stream nutrient loadings, their results suggest that effects of agricultural practices on phosphorus concentrations in the Salt Fork are minimal compared with urban influences. This statement takes on even more importance when one realizes that the land use in the watershed is 90 percent agriculture and 5 percent urban. Nitrate concentrations appear to be associated with agricutural practices during the late winter and spring when fertilizers are applied to the fields, but is more closely related to urban inputs during summer and autumn. Therefore, the present research emphasis on agricultural impacts in Midwestern streams may be misplaced if the objective is to reduce nutrient concentrations in the streams. Planners and watershed managers must be aware not only of the dynamic nature of stream systems but also of the temporal variability and relationships between components of the watershed.

This research was funded by a grant from the Department of Energy and Natural Resources.

By *Jana Waite, Section of Aquatic Biology*

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NATURAL HISTORY SURVEY

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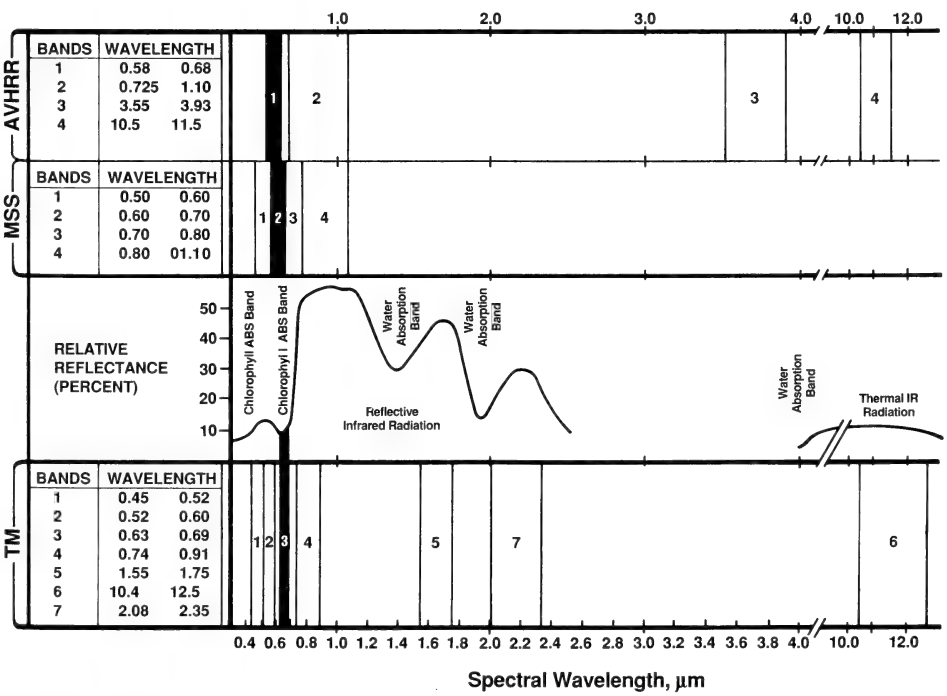
Can the Productivity of Forests Be Estimated from Space?

Though estimates from space may seem farfetched, scientists in the Section of Botany and Plant Pathology, under contract with the National Aeronautics and Space Administration (NASA), are investigating the feasibility of determining the productivity of forests by using satellite-collected information.

Civilian satellites from the United States, France, Japan, and other countries continually circle the globe, producing images of large portions of the planet on every cloudless day. The images are transmitted to computers at various locations on earth and made available worldwide to researchers and land managers. In many cases, especially in remote areas, satellite imagery provides the only feasible method of obtaining landscape information. In well-known areas like most of this continent, satellite imagery provides up-to-date information at high resolution, information that would be extremely costly to acquire by other means.

Currently three United States satellite sensors image the globe: Landsat Thematic Mapper (TM), Landsat Multispectral Scanner (MSS), and the Advanced Very High Resolution Radiometer (AVHRR). Each sensor has its own spectral and spatial attributes and each



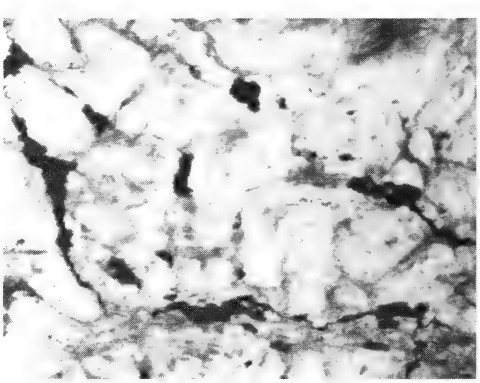
Wavelengths recorded by each of three U.S. satellite sensors. Also shown is the absorbance spectrum for green vegetation.

has four to seven channels of data collected across various bands of the electromagnetic spectrum. These bands match certain reflectance patterns of the landscape, thereby giving vegetation and other land cover classes unique spectral signatures. A vigorously growing deciduous forest, for example, reflects highly in the infrared band (TM Band 4, MSS Band 4, and AVHRR Band 2). Water, however, absorbs light and therefore reflects little in the reflective bands. Because the spectral signatures are unique, maps showing vegetation and other land cover can be readily generated with computer algorithms. Similar technologies enable us to detect subtle differences among forest classes and to relate these to differences in site quality, species composition, and forest biomass or productivity. Analyzing these subtle differences is the thrust of the current project.

The three sensors vary widely in spatial resolution. The TM sensor can resolve features on the ground as small as 30 meters, a picture element (pixel) size of less than 0.25 acre. It therefore records a massive amount of data and can image the entire globe only every 16 days. The AVHRR sensor has a resolution of 1.1 kilometers and images the entire globe each day. The MSS sensor has a resolution of 80 meters. Because it resides on the same satellite as TM, it also images the globe every 16 days.

In addition to satellite data, numerous other data sets are important in predicting forest productivity. The Geographic Information System (GIS), operated by the Illinois Department of Energy and Natural Resources, is one of the most sophisticated in the world. The data base is managed with ARC/INFO software, the current leader in vector-based GIS software, on four large Prime computers. Among the billions of pieces of information about the natural resources of the state are county soil survey maps. The detailed soils information provided by these maps can be overlaid with Landsat TM data, thereby enabling us to discern relationships between indexes of soil productivity and forest productivity. Information on land forms (for example, bottomlands vs. uplands) is also included. Detailed vegetation maps are digitized from interpreted aerial photographs and provide a means for checking TM classification and for analyzing forest classes in even greater detail. Finally, data collected from sample forest plots provide the integral link between what is seen from space and what is happening on the ground. Numerous permanent plots accurately located via a map coordinate system from which measurements of tree growth are recorded over time are needed for accurate forest productivity estimates. Measurements of forest productivity obtained from these sample plots are then statistically related to the TM and GIS variables to assess the feasibility of estimating forest productivity from space.

The research is concentrated in three locations—the Shawnee National Forest in southern Illinois, the Great Smoky Mountains in Tennessee-North Carolina, and the Adirondack Mountains in New York. Within these large areas, smaller study sites of roughly 400 square kilometers were selected for concentrated study: portions of several counties in southern Illinois; Cades Cove 7.5-minute quadrangle in the Great Smoky Mountains; and the Huntington Wildlife Forest of the central Adirondack Mountains. These sites were selected because TM, GIS, and forest productivity data of good quality were



TM Band 4 (near infrared region of the spectrum) image of the Huntington Wildlife Forest in the central Adirondack Mountains in New York. The darkest areas are water, followed in increasing intensity by vegetated marches, conifer forests, and deciduous forests.

available for them, in addition to the diversity of forest ecosystems they encompass.

The procedure followed in the study is to precisely register all data sets geographically to a common coordinate system and then to statistically analyze the relationship of the spectral and landscape variables to the estimates of forest productivity obtained on the ground. The following results from the Huntington Wildlife Forest are representative of all the study areas.

The data used in making the regression and correlation analyses included the seven TM bands from two TM scenes (June 17 and September 21, 1984), various ratios of the TM bands including ratios between the June and September dates, slope angle, slope aspect, potential sun radiance (calculated for slope aspect and slope angle at a given latitude), and site index as an estimate of woodland productivity based on soil characteristics. The ground information was taken from 173 continuous forest inventory plots which had measurements taken in 1970, 1976, and 1981. From these data and published biomass regression equations, forest productivity was estimated as the total change in live above-ground biomass at each site per year (kg/ha/yr).

Results of this work indicate potential for predicting forest productivity using spectral and soil information. The best four variables—the ratio of middle infrared to near infrared (TM Band 5 to TM Band 4), site index, sun radiation index, and ratio of the two red regions of the visible spectrum (TM Band 3 in June to TM Band 3 in September) allowed a significant predictability of forest productivity.

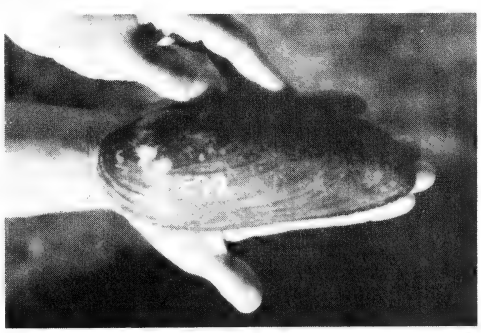
If forest productivity estimates from space can be refined sufficiently, the dividends would be large. Accurate forest data will enable us to manage our remaining forests more wisely and to track areas undergoing rapid forest gain or loss. The study is also investigating the use of high-resolution TM data to calibrate the coarse-resolution AVHRR data. This procedure could allow projections about forest productivity across continents, thus reducing both the cost and volume of data for global carbon studies important to current and future ecological research.

By *Louis R. Iverson and Elizabeth A. Cook, Section of Botany and Plant Pathology*

Kankakee River Mussel Relocation

The freshwater mussel fauna of North America has undergone an alarming decline over the past century. Populations have decreased in size, and the range of many species has shrunk or disappeared altogether. The decline in the fauna resulted with the growth of urbanization, industry, and agriculture throughout North American watersheds and points out the sensitivity of mussels to human activities. Concern for this declining resource has led to the listing of several species as endangered or threatened at both the federal and state levels. In addition, both federal and state conservation agencies have recommended that significant mussel populations ("beds") be protected also from adverse affects of construction and other activities.

Zoologists determining the density of mussels in the Kankakee River (photo by Mark Wetzel).



Mussel that has been marked for return to the Kankakee River (photo by Mark Wetzel).

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The Kankakee River is one of the few streams in Illinois where dense, diverse mussel populations still exist, supporting the richest mussel assemblage of any in the state. In August of 1984, Illinois Natural History Survey (INHS) personnel conducted a preliminary survey of Kankakee River mussels in the immediate vicinity of the Washington Avenue Bridge (U. S. Routes 45 and 52) in Kankakee, a bridge proposed for removal and reconstruction by the Illinois Department of Transportation (IDOT). During that survey, 579 mussels representing 17 species were collected, identified, and placed live back into the river.

Subsequent to that preliminary survey and upon the recommendations of the U.S. Fish and Wildlife Service and INHS personnel, IDOT requested that the INHS remove mussels from the immediate vicinity of the Washington Avenue Bridge and relocate them to suitable habitat either upstream or downstream of the impact area. Although several mussel relocation projects have been conducted in other states, few have followed the relocation with long-term monitoring in order to determine the efficacy of relocation.

During August and September 1987, INHS personnel, under the direction of Survey malacologist Jeanine M. Berlocher and zoologist Mark J. Wetzel, completed the first phase of the Washington Avenue Bridge mussel relocation project on the Kankakee River. The objectives of the first phase of the project were: 1) To evaluate several Kankakee River localities upstream of the city of Kankakee as potential sites for receiving relocated mussels; 2) To select and establish plots into which relocated mussels were to be placed; and 3) To remove mussels from the area to be affected by the removal and reconstruction of the Washington Avenue Bridge, mark them, and place them into the relocation plots.

Over 4,000 live unionid mussels representing 20 species were marked and placed into plots during the initial phase of this project. Objectives of Phase 2 of this project include: 1) Estimation of density and distribution of mussels downstream of the direct impact area associated with the reconstruction of the Washington Avenue Bridge during 1988; and 2) Monitoring of the relocated mussels, including growth, movement of plots, and mortality after 1 year. Phase 3 of this project will include: 1) A resurvey of the Washington Avenue Bridge site after construction has been completed to determine whether this area was affected adversely; and 2) Annual surveys for at least 5 years to monitor both the relocated mussels as well as the recolonization of the construction site.

By *Jeanine M. Berlocher and Mark J. Wetzel, Faunistic Surveys and Insect Identification Section*

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Bellrose Anniversary Celebrated

A half century ago, before most of the present employees of the Illinois Natural History Survey (INHS) were born, Dr. Frank Bellrose, Principal Scientist at the Natural History Survey, received a B.S. degree from the University of Illinois and then accepted a position with the Survey February 1, 1938.

On February 1, 1988, the INHS held a reception at the Natural Resources Building, Champaign, to recognize Frank's remarkable record. Frank's classmates at the University included George Fell, Eugene P. Odum, Louis G. Brown, Frank Pitelka, Ted Black, and Richard Costley. As a student, Bellrose attended the first Midwest Wildlife Conference held in Urbana December 5–7, 1935. Dr. Frison, then Chief of the INHS, was primarily responsible for the conference and gave the opening paper. This conference was the first regional one on wildlife held in the United States. Because the conference was not held during World War II, the 50th Midwest Wildlife Conference will be held in December 1988 in Columbus, Ohio.

Dr. T.H. Frison, who became Chief July 1, 1931, was an enthusiastic hunter. He gave wildlife research its first place in the organizational structure of the INHS July 1, 1934 with the establishment of a Section of Game Research and Management. Dr. Frison hired Frank and Art Hawkins to work on wildlife problems related to the construction of levees by the Corps of Engineers at the junction of the Illinois and Mississippi rivers in Calhoun County. Art and Frank began their work on Calhoun Point but Frank spent his weekends in Havana and

DR. FRANK BELLROSE

decided that Havana was a better location for their work. They moved their operations to Havana and then wrote to the Chief to tell him what they had done. Dr. Frison said "Okay for now, but you will move back when they impound Pool 26." Art soon joined the Army. He returned to the Survey after the war, but later accepted an offer from the U.S. Fish and Wildlife Service. Frank remains in Havana today. He semi-retired August 31, 1982; however, he continues to work on a part-time basis to complete several of his long-term research projects, especially a book based on nearly 50 years of research on the wood duck.

Bellrose checks a wood duck box in the earlier days (1950) of his long career with the Survey (photo by C. L. Scott).

In recognition of his long and productive career, Western Illinois University, Macomb, awarded Frank an honorary ScD degree in June 1974; the first such degree awarded by that university. Dr. Bellrose has published more than 110 scientific and popular articles, plus a countless number of reports. Most of his research and his publications relate to waterfowl and wetlands, with a strong flavor of "conservation" issues; however, some of his earlier studies were on quail, pheasants, small mammals, and muskrats. His best known publication is the book, "Ducks, Geese & Swans of North America," which has sold more than 250,000 copies. This number is far larger than for the sale of any other book on a subject related to wildlife or conservation.

Dr. Bellrose's peers and the conservation community have honored him many times, the most recent of which was presentation of a special award on January 26 this year at the symposium "Habitat Management for Migratory and Wintering Waterfowl in North America" in Jackson, Mississippi.

In addition to the degree from Western Illinois University in 1974, Frank has received awards from the Association of Great Lakes Outdoor Writers, 1956; Alton-Wood River Sportsmen's Club, 1962; Migratory Waterfowl Hunters, Inc., 1972; State of Illinois, Superior Achievement Certificate, 1972; Arkansas Wildlife Federation, 1973; Mississippi Flyway Technical Committee, 1976; Publication Award (book), The Wildlife Society, 1976; Oak Leaf Award, The Nature Conservancy, 1977; The Illinois Chapter, The Wildlife Society, 1979; American Motors, Conservation Award, 1979; National Wildlife Federation, Conservation Award, 1980; U.S. Department of Interior, Conservation Award, 1980; Outstanding Achievement Award, Association of Midwest Fish and Wildlife Agencies, 1982; Honorary Member, The Wildlife Society, 1982; U.S. Fish and Wildlife Service, Special Agents Award, 1982; "Waterfowl Ecology and Management: Selected Readings" which was dedicated to Frank, 1982; Alexander-Griswald Marsh, Manitoba, dedicated to Frank by Illinois Chapter, Ducks Unlimited, 1983; Aldo Leopold Award, The Wildlife Society, 1985; Senate Joint Resolution No. 40 that recognized and commended Bellrose was passed April 18, 1985 and concurred in by the House of Representatives on April 12, 1985.

By *Glen C. Sanderson, Section of Wildlife Research*

Study of Illinois and Tennessee Minnows

Sometimes it is necessary for Illinois Natural History Survey (INHS) scientists to conduct studies outside Illinois. Environmental factors do not recognize state boundaries, and conditions outside the state have an impact on decisions made in Illinois. A recent study of Illinois and Tennessee minnows by Survey ichthyologist Dr. Lawrence M. Page is a case in point.

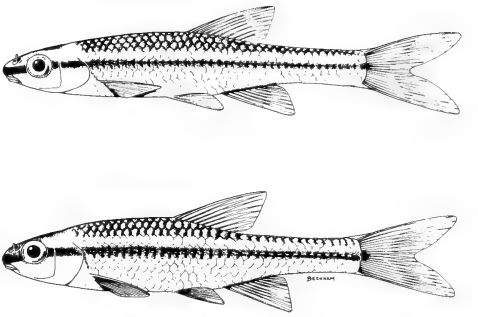
The blacknose shiner, *Notropis heterolepis*, ranged historically over a large portion of North America, extending across Canada from Saskatchewan to Nova Scotia and as far south in the United States as Kansas, Missouri, Il-

linois, Indiana, and Ohio. Until recently, the blacknose shiner was thought to occur also in central Tennessee.

Although the blacknose shiner remains widespread and common in the northern part of its range, numbers are declining rapidly in the south and it has been declared a protected species in Illinois, Ohio, and Missouri. In these states a majority of the historically known populations have disappeared in recent decades and surviving populations have decreased in size. In Illinois the number of known populations has decreased from 33 in 1900 to 13 at present, and the range has dwindled from essentially statewide to only the northern one-third of the state. The species has been considered endangered in Illinois since the first list of endangered fishes was compiled by the Illinois Endangered Species Protection Board in 1979.

One of the most perplexing aspects of the decline of the blacknose shiner has been the status of the Tennessee population. Although restricted to five counties in central Tennessee in an area known as the Nashville Basin, the Tennessee population is large and thriving. In fact, in the small streams within the area, the backnose shiner is the most common species. Why are other southern populations of the blacknose shiner declining so dramatically, while the Tennessee population, at the southern extreme of the range, is thriving? Are environmental conditions better suited to the species in Tennessee, or is the Tennessee population genetically different from other populations? To address these questions and to develop management ideas for Illinois populations, Dr. Page undertook a study of geographic variation in the blacknose shiner, emphasizing Illinois and Tennessee populations.

The results of the study show that the Tennessee population is genetically different from other populations and, in fact, is not even the blacknose shiner. It is a distinct species, similar to and closely related to the blacknose shiner, but it differs in a number of morphological characteristics, including body shape and numbers of scales and gill rakers.



The blacknose shiner (top) is endangered in Illinois. The bedrock shiner (bottom) is a common, closely related species in Tennessee (drawings by Page and Beckham).

The Tennessee species, now described and named the bedrock shiner, *Notropis rupestris*, by Dr. Page, also differs from the blacknose shiner in its ecological characteristics. The bedrock shiner occupies rocky pools in headwaters and creeks, whereas the blacknose shiner lives in glacial lakes and small, low-gradient, sand-bottomed streams. Both species prefer clear water and usually are found near aquatic vegetation.

The study resulted in the recognition and naming of a new species, and revealed that we cannot look to the Tennessee population for management suggestions for Illinois populations. It also told us that all of the southern populations of the blacknose shiner are declining and that there is an even greater urgency than was realized before in protecting those that remain.

By *Lawrence M. Page, Section of Faunistic Surveys and Insect Identification*

Controlling Aquatic Vegetation with Triploid Grass Carp

The control of aquatic vegetation is a difficult problem for managers in Illinois and many other states. Methods currently available include benthic barriers, harvesting, shading chemicals, aquatic herbicides, and fertilization. A combination of techniques often gives the best results.

Managers now have a new tool in their arsenal of control techniques. In a recent publication from the Natural His-

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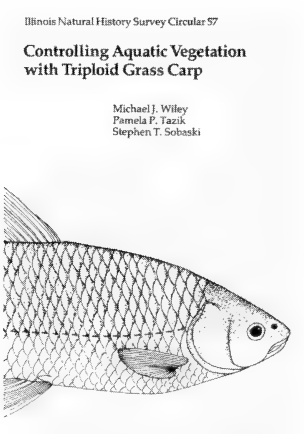
tory Survey, Michael J. Wiley, Pamela P. Tazik, and Stephen T. Sobaski describe the use of a fish for the control of aquatic



Cover of new publication (photo by Molly Hardin Scott).

vegetation. Although the possession or stocking of diploid grass carp in Illinois is illegal, the sterile triploid grass carp may be used legally to control aquatic vegetation in this state. Both diploid and triploid grass carp have large appetites for vegetation and grow rapidly; two factors that make them effective for controlling aquatic vegetation. Because the triploid grass carp cannot reproduce, there is no concern for its uncontrolled spread.

In some cases triploid grass carp provide an efficient and cost effective method for controlling aquatic plants. Major considerations in the effectiveness of triploid grass carp are the species of plants to be controlled and the climate. Control by this method is more effective when the plant to be controlled is highly palatable to the grass carp and when the pond or lake is located in a warmer part of the state.

In this publication the researchers present recommendations for stocking rates that are based on a series of analyses that use the Illinois Herbivorous Fish Stocking Simulation System, a computer model developed at the Natural History Survey. The computer program couples bioenergetic and feeding characteristics of the triploid grass carp with the population dynamics of each species of plant to estimate a level of plant control that can be obtained with various stocking rates. Managers must determine the surface acres of the pond or lake for which control is desired, determine the percentage of the water area that is heavily vegetated when plant cover is at its annual peak (typically in July or August), determine the percentage of water area that is less than 8 feet deep, identify the species of plant to be controlled, and identify the climatic region of the pond or lake.

By *Glen C. Sanderson, Chairman, Publications Committee*

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Shiitake Production Combines Economics and Conservation

A solution to the farm crisis will include more diversified crops. Diversification for economic reasons alone, however, will not provide a complete or lasting solution. The farm crisis is also an environmental crisis, and new cropping systems are needed that protect the soil, require fewer chemical inputs, and restore wildlife habitat. From an environmental perspective, trees are among the most promising alternative crops, but most farmers cannot afford the long wait required before tree crops mature. Fortunately, the production of shiitake (shea-ta-kay) mushrooms promises to provide one solution to this dilemma.

Shiitake are highly prized edible mushrooms that grow on dead wood in eastern Asia. Methods of controlled cultivation were developed in Japan in the 1940's, and today, shiitake production is a major industry in the Orient. Holes are drilled in freshly cut logs, and pure strains of the fungus in the form of wooden plugs or sawdust are placed in the holes. Subsequent management consists primarily of regulating the moisture content of the logs by a variety of simple methods. Mushrooms begin to appear on the logs in about a year, but fruiting continues one or more times a year for several years. Markets for shiitake in the United States are expanding rapidly, and commercial operations are springing up wherever the forests and climates are suitable.

Oak logs are preferred for shiitake production, but many other species can be used also. Logs about 4–6 inches in diameter and 3 feet long are the best for cultivating shiitake. Consequently, shiitake logs can be obtained from trees that are thinned for timber stand improvement and from the tops of trees harvested for timber. Currently, many woodlands go unthinned and tops are unused because of the low economic

Shitake mushrooms being harvested from oak logs by Ken Konsis of the Vermilion County Conservation District (photo by Richard Stefaniak, Danville).

Oak logs inoculated with shitake mushroom spawn incubating in the "laying yard" at Kennekuk Cove County Park near Danville, Illinois (photo by Richard Stefaniak, Danville).

value of short, small diameter logs. Thus, shiitake production complements conventional timber production practices and can make such operations economically more attractive. In addition, the relatively short time required to grow logs from which shiitake can be produced provides a much-needed incentive for planting trees on eroding cropland.

In order to investigate the feasibility of shiitake cultivation in Illinois, Survey ecologist Christopher Burnett established a cooperative project with the Vermilion County Conservation District in the spring of 1986. Investigators are screening shiitake strains for adaptation to the Illinois climate and comparing the production rates obtained from various types of logs and log management methods. Because of the highly attractive economics of shiitake production, there is danger that existing woodlands could be exploited. Consequently, ecologists are working on the development of woodland management practices that efficiently produce sustained yields of shiitake logs and environmental benefits.

Early yields from some of the strains under investigation have been very good and demonstrate that commercial shiitake production in Illlinois is technically feasible. Encouraged by these results, as well as similar findings in other midwestern states, a series of public workshops on the technical, economic, and environmental aspects of shiitake production were conducted during the winter of 1987–1988. The workshops were well attended; and several Vermilion County landowners will begin growing their own woodland mushrooms this spring.

By *Christopher D. Burnett, Section of Wildlife Research*

Squash Bugs in the Pumpkins and in the Zucchinis

Wherever pumpkin or squash (*Cucurbita spp.*) is grown in North America, squash bugs are usually there sucking vital juices from the plants. Cultivated varieties of *Cucurbita* originated in central America several thousand years ago. Survey investigator Dennis Fielding believes it likely that the squash bugs followed as squashes were introduced from tropical America to eastern North America by indigenous tribes about 3,000 years ago.

Today Illinois is the largest producer of pumpkins for processing; and increasing numbers of farmers are growing zucchini and other squashes for fresh markets. Even though the squash bug is a major pest of these crops, little is understood of its biology or ecology. In 1984, a study of squash bug population dynamics was begun.

The squash bugs overwinter in the adult stage. In late spring, the adults leave their overwintering sites to search for squash plants. In central Illinois, oviposition usually begins in late June and continues to mid-August. Eggs are laid in clusters usually on the underside of the leaves. The immature nymphs molt five times before attaining adulthood. The new adults will then either produce second-generation offspring, if the season is long, or will begin to prepare for hibernation.

One factor that determines the rate of population increase during the summer is the speed at which the eggs and nymphs develop. As cold-blooded animals, the squash bugs rate of development depends on temperature. Like their host plants, these bugs love warm weather. At 95°F in the laboratory, they grow from egg hatch to adult in about

Two fully developed squash bugs on a squash leaf (photo by Dennis Fielding).

Dr. Lewis J. Stannard

Dr. Lewis J. Stannard died at his home in Golconda, at 5:00 a. m., Sunday, January 17. Before he retired in 1976, Dr. Stannard was an entomologist at the Illinois Natural History Survey and a Professor of Entomology at the University of Illinois.

During his tenure at the Survey, Dr. Stannard published many papers on the systematics of insects and became one of the world's leading experts on Thysanoptera. His book, *The Thrips, or Thysanoptera of Illinois*, is a landmark contribution to systematic entomology. His scientific studies included field work in Europe, Asia, and Africa, as well as many regions of North America. In recognition of his scientific contributions, Dr. Stannard was named a Guggenheim Fellow, a Fellow of Royal Entomological Society, and a Fellow of the Entomological Society of America.

As an ardent conservationist, Dr. Stannard was instrumental in the preservation of several important natural areas in Illinois and was a past president of the Illinois Chapter of the Nature Conservancy.

Memorial services will be held at 2:00 p. m., Saturday, March 26, 1988, at the Methodist Church in Golconda.

By *Lawrence M. Page, Section of Faunistic Surveys and Insect Identification*

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16 days. Nymphs fail to grow at constant temperatures below 68°F. However, under field conditions, it was observed that nymphs may elevate their body temperatures as much as 20°F above air temperature by basking in sunlight. It was also noted that nymphs reared at cool temperatures were darker than those reared at warmer temperatures, apparently due to melanin deposited in the exoskeleton during molting. Using a spectrophotometer to measure the amount of light reflected from light and dark nymphs, it was determined that nymphs reared at 73°F absorbed about 20 percent more solar energy than lighter colored nymphs reared at 95°F. This color adaptation may be especially useful to nymphs later in the season when cool weather is hindering development.

Another factor controlling the squash bug population dynamics is diapause. Diapause in squash bugs is characterized by the cessation of reproductive activity and by a gradual decline in metabolism to a level less than half the normal rate. Since squash bugs must overwinter as adults, any eggs laid too late in the season to reach adulthood before cold weather arrives represent wasted reproductive effort. Diapause is an adaptation that serves to prevent such wasted effort and to prepare the adults for hibernation. Squash bugs are long-day insects, i. e., the long days of summer maintain reproduction in the population, while short days will induce diapause. In central Illinois, the day length in early August is already short enough to begin to induce diapause. Bugs maturing after this time will forego reproduction until the following year.

Information regarding developmental rates and the timing of diapause, plus information regarding mortality rates and oviposition rates, was incorporated into a computer model that simulates the

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growth of a squash bug population over a single season. This model was then used to identify factors having the greatest impact on squash bug populations and to suggest management strategies for this pest. Mortality rates of the various stages were shown to have the greatest impact on population size. This is also one of the most difficult areas to study. The time when overwintering adults break diapause and begin oviposition was also an important factor determining subsequent population growth. Even though temperatures in May and early June are favorable for squash bug development, oviposition rarely begins until late June. The relatively late start squash bugs get in the spring may be an adaptation to ensure the widespread availabilty of host plants when overwintering adults emerge from hibernation.

The effect of planting dates and chemical application dates were analyzed using the model. Early planting dates were the least favorable for squash bug population growth because the correspondingly early harvest dates (assuming crop destruction at harvest) cut off the population at lower levels. Late planting dates, (late June) also were unfavorable for squash bug populations because of mortality of overwintering adults before the host plants germinated.

By *Dennis Fielding, Economic Entomology Section*

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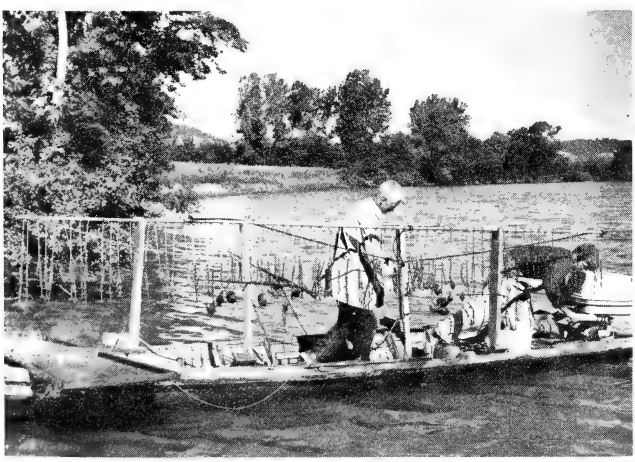
Mussel Die-offs of Biological or Chemical Origin?

Unexplained die-offs of freshwater mussels occurred in the Mississippi River, including its waters in Illinois, starting in 1982 with major episodes reported again in 1983 and 1985. Illinois Natural History Survey (INHS) biologists documented a die-off in Mississippi River pools 14 and 15 in 1983—33 percent of the mussels collected had died during the previous year. Research to determine whether the cause of these die-offs is of biological (a disease or parasite) or chemical (pollution) origin is a cooperative effort among biologists Richard Sparks and Douglas Blodgett of the Survey's River Research Laboratory (RRL) on the Illinois River near Havana and fish pathologist Rod Horner and microbiologist Larry Durham at the Illinois Department of Conservation's (DOC) Jake Wolf Memorial Fish Hatchery near Manito.

Freshwater mussel shells are harvested commercially from rivers in Illinois and other midwestern states and sold to the Japanese for use in the cultured pearl industry. According to records compiled by the DOC, shell buyers paid $658,836 for 1,358 tons of shells taken from Illinois waters in 1986.

By filtering fine particles of organic matter, bacteria, and algae from water, mussels are also valuable as waste assimilators and purifiers of streams and rivers. Large beds of mussels may have a filtration waste removal capacity equivalent to that of a sewage treatment plant. In addition, they often provide the only solid substrate for other organisms in streams and rivers which have shifting bottoms of sand or silt.

Mussels are used in basic research in ecology and evolution and are good pollution monitors because they are long lived, stay in one place (in contrast to fish), and filter particles including contaminants from the water. Contaminants accumulate in the mussel's soft tissues and shells. Because mussels produce shells with annual rings, scientists can use them to reconstruct the chronology of pollution or contamination.



Typical crowfoot bars used by commercial fishermen for catching mussels in the Illinois River. The Survey crowfoot bars are a little shorter because the boats are smaller (photo by Alvin C. Lopinot).

In spring 1987, researchers from the INHS River Research Laboratory collected healthy mussels from the Illinois River where no die-offs were reported and stocked them into raceways at the DOC's Jake Wolf Fish Hatchery. In the event of another die-off, dead and moribund mussels will be collected and placed into raceways with the healthy ones. If the healthy mussels become sick, it will indicate that the cause is an infectious agent transmitted from dead or moribund individuals. If the healthy mussels are unaffected, it will indicate that the die-off was caused by an environmental factor such as some contaminant released into the water. No substantial mussel die-offs were reported from the Mississippi River in 1987. However, raceways at the hatchery will be restocked with Illinois River mussels in spring 1988, and researchers will be prepared to collect specimens, should another die-off occur.

In June 1986, the U.S. Fish and Wildlife Service and the Upper Mississippi River Conservation Committee cosponsored a workshop to discuss the mussel die-offs. Mussel die-offs were reported in 13 major rivers and 40 large lakes in the eastern United States and Canada during the last decade. The die-offs may signal the presence of a new contaminant in the aquatic environment or transmission of a disease from the introduced Asiatic clam, *Corbicula fluminea*, to which the native mussels are not resistant. Little is known about the microbial flora normally found in and on freshwater mussels. Scientists had no basis to determine whether the bacteria they discovered in dying mussels had caused the die-offs or were species routinely associated with mussels.

Research funds from the Department of Energy and Natural Resources are providing an opportunity to investigate the commensal microflora associated with the healthy freshwater mussels. Durham and Horner have developed techniques for sampling the bacterial fauna of various mussel tissues.

Over 20 species of bacteria have been identified from mussels collected in 1987. This search will continue through 1988 with additional mussels to be stocked this spring.

By *K. Douglas Blodgett and Richard E. Sparks, Section of Aquatic Biology*

Alkaline Hydrogen Peroxide-Treated Straws as Feeds for Crayfish

Aquaculturists of crayfish in ponds either ignore the feed aspect or refer to forages planted and tested as feeds. Few data are available regarding the nutritional requirements and feeding preferences of crayfish. The main food for *Procambarus clarkii*, the red swamp crayfish, is decaying vegetation and associated protein-rich microbes, and the timing of forage decomposition and the extension of forage available throughout the growing season are critical to the growth of crayfish.

In Louisiana, rice (occasionally soybeans) is the usual crop planted as forage in crayfish grow-out ponds. A major problem is the maintenance of forage material throughout the winter growing season and into the spring harvest period. Labelle rice is considered superior to Saturn rice as forage.

Laboratory studies have suggested that rice bran surpassed other tested feeds of either plant or animal origin as a feed for red swamp crayfish. The optimum protein to energy ratio for that organism is 30 percent protein: 2.5 kcal energy/g with a diet lipid level of <9 percent, i.e., close to 6 percent lipid.

Research leading to the development of improved feeds for crayfish as either primary or supplementary feeds was conducted at the Survey and was supported by E. I. DuPont de Nemours Company, the U.S. Department of Agriculture (USDA) Laboratory at Peoria, and the Illinois Natural History Survey. Procedures for treating straws and other agri-wastes were developed in the laboratory of Dr. Mike Gould, USDA, Peoria, and modified by scientists at DuPont. Basically, the treatment involves exposure of straws to 2 percent H_2O_2 and 5 percent NaOH for varying periods of time. Treated straws are delignified with cellulose molecules readily available to

The crayfish, *Procambarus acutus*, indigenous to southern Illinois, is now being fed the experimental feeds (photo by Lawrence Page).

the enzymes of various types of cellulose-degrading bacteria.

First tested in the diets of ruminants, alkaline hydrogen peroxide (AHP)-treated wheat straw was readily consumed by sheep and was capable of replacing up to 70 percent of the corn in their diet. Test animals receiving 70 percent of their diet as AHP-treated wheat straw grew as rapidly as did those on the control diet. Subsequent experiments have demonstrated that AHP-treated wheat straw is capable of replacing a major portion of the diet of growing ruminants, including sheep and cattle, but is less effective in the diet of non-ruminant organisms.

The primary purpose of this study was to determine the effect of four different consortia of cellulose-degrading bacteria on AHP-treated and untreated straws in an aerobic environment. If one or more of the bacterial consortia can increase the energy and nutritional value of one or more of the straws, the straw plus bacterial inocula would be a valuable, cheap feed for crayfish.

In Phase I, AHP-treated and untreated wheat and rice straws and bagasse (sugar cane fibers) each were inoculated with four consortia of cellulolytic, facultatively aerobic bacteria and incubated for 6 days aerobically at room temperature. The caloric value, protein content, percent carbon, and percent hydrogen all increased more in wheat straws than in rice straw or bagasse.

Juvenile crayfish grew most rapidly on pelleted, 28 percent protein commercial feed followed by AHP-treated wheat straw. Animals on untreated wheat straw and treated bagasse showed slight weight gains while those fed untreated bagasse and AHP-treated rice straw had little growth or weight gain. Our data show that treated straws will support the growth of crayfish but the straw plus bacteria lack the complete nutritional requirements for *Procambarus acutus*, the White River crayfish common in Illinois waters. We are now conducting feeding trials using *P. clarkii*, which is also indigenous to southern Illinois.

By *R. W. Gorden, Head, Section of Aquatic Biology.*

Plant Cell Response to Stress

The cell is the basic building block of organisms. The outer boundary of the plant cell is defined by a rigid cell wall. The cell wall is lined on the inner side by a membrane. While the cell wall is permeable to water and solutes, the membrane is semipermeable, that is, water moves freely through the membrane while solutes do not.

The semipermeable cell membrane plays a very important part in plant growth. As the cell accumulates sugars,

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salts, and other solutes, the energy level of the cell cytoplasm is lowered and thus the freely moving water flows into the cell causing the pressure of the cell to increase. Cell or plant growth occurs when the internal pressure or force of the cytoplasm is great enough to overcome cell wall resistance. That is, with sufficient outward pressure, the rigid cell wall will stretch and cell growth will result. An increase in cell membrane permeability allows solutes to leak from the cell interior and thus the pressure that can develop as water flows inward (potential pressure) within the cell is reduced. Under these conditions growth does not occur or is, at least, reduced.

Most stresses, whether environmental or man-made, affect membrane permeability, and it is usually manifested by an increase in permeability. Stress affects both the chemical composition of membranes as well as the physical arrangement of the protein-lipid biomolecular leaflets or membrane bilayer. For example, the water-soaking appearance of leaves exposed to sulfur dioxide, an important air pollutant, is due to a change in membrane permeability. While the exact mechanism of action is unclear, it has been suggested that the pollutant affects the lipid component of membranes. Similar findings have been reported by Survey scientists using ozone, water, and light stresses. Survey scientists have focused their research on one of the lipid components (sterol) of the membrane bilayer. Their working hypothesis is that as the plant is exposed to stress, the sterol component of the membrane changes in structure, it becomes more bulky, and thereby lowers the condensing characteristic on the membrane lipid bilayer. An oversimplification would be to think of creating larger or more pores, or holes, in the membrane bilayer, thus making it more leaky. Once the stress is released, the plant cell in essence repairs the damage and the higher semipermeability level is reestablished. It is the goal of Survey researchers to establish the mechanism, or site of biochemical control, and to find ways to minimize or regulate the negative plant growth effect.

By *Claus Grunwald, Section of Botany and Plant Pathology*

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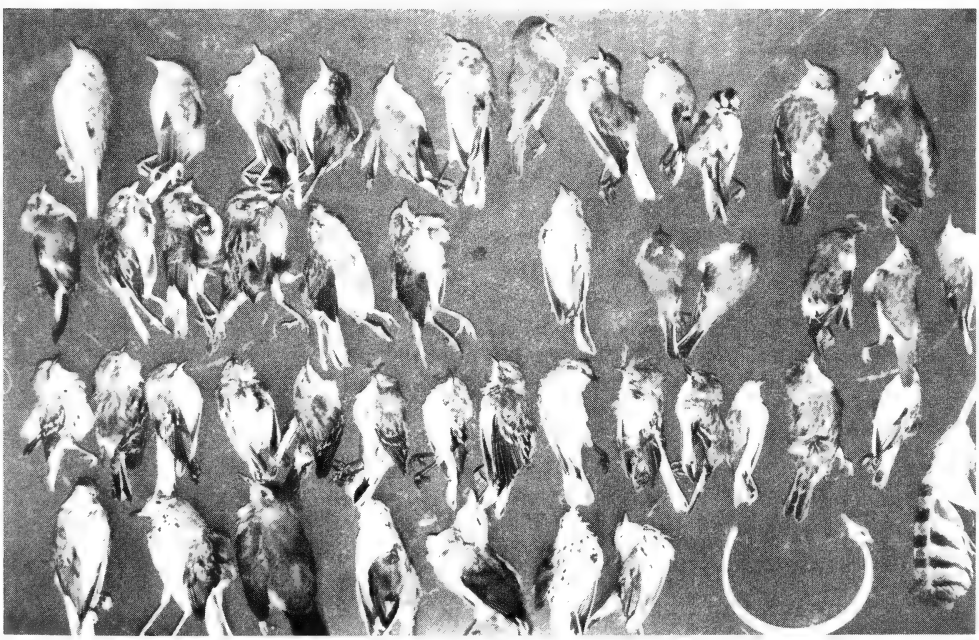
Why Are Migrating Birds Killed at Tall Structures?

A large number of birds reside in Illinois only during the summer, migrating here from their tropical homes to breed and to grace our landscape with their songs and beautiful colors. A still larger number of birds pass through Illinois twice each year to reach breeding grounds to the north. The great majority of migrants travel at night, for reasons that are not fully understood but probably involve security from the sun's heat and from flying predators.

However during the last 30 years man has erected a danger to migrating birds from which evolution has not had a chance to protect them—lighted television towers and buildings tall enough to be encountered by birds flying hundreds of feet above the ground at night. In the morning after a cloudy night in the fall, one can often find many dead or injured birds beneath a tall tower. Occasionally hundreds of birds may be killed at one tower in one night. The birds are usually killed by colliding with the structure or with guy wires, although at lighted television towers most of the mortality probably occurs from the guy wires. Incidents occur on nights with low clouds, not on clear nights.

An important step toward understanding these annual tragedies was taken some years ago when Natural History Survey scientists Richard Graber and William Cochran conducted studies of killed birds, and even augmented these studies with intrepid observations conducted by climbing a tower at night. They found that birds, once near the tower, behaved as if they were reluctant



These 45 birds were killed in one night at a tower in Illinois (photo by Douglas Quine).

to fly away from it, turning back again and again to expose themselves to the danger of hitting a part of the structure. Graber likened the birds' behavior to that seen indoors at night, when birds refuse to leave a lighted room to fly into a darker place. (Zoo aviaries use this principle to keep birds in lighted exhibit areas and away from darkened visitor areas.) Cloud plays a part by creating a relatively bright, diffusely lit zone near the tower—a zone of danger the birds are not equipped to handle.

Survey scientist Ronald Larkin recently had the opportunity to provide a different outlook on the problem of "tower kills" by using radar near a tall tower at night. On many nights with clear or broken cloud, the radar-tracked birds ignored the tower completely as they flew by it straight and level. However, one night in September a thin but unbroken light cloud enveloped the tower and descended almost to ground level, whereupon some birds started to show unique and bizarre behavior. Approaching the tower to a distance of 100 meters (about 100 yards) or more, they started to circle it slowly in the night, maintaining their distance as if they were tethered on a long string. At the center of each arc or near circle was the tall tower.

The radar could not track birds close to the huge metal tower, so that very small circles within the guy wires could not have been observed had they occurred; however, no dead birds were found beneath the tower the next morning, indicating that there had not been a severe kill. Therefore, we suppose that the cloud was too thin to entrap birds so close that they struck the tower, but was thick enough that some birds became "trapped" in the zone of dim red light created by its lights. Wingbeats were recorded by the radar unit, so there was no doubt that small birds rather than insects were responsible for the strange tracks.

The radar observations lend strong support to Graber's ideas and provide further clues to what happens on a cloudy night at tall towers. First, there was no evidence that the towers exerted an attraction to the birds from a distance. Rather, the birds that circled the tower simply seemed to happen upon it during the course of of a long flight. Second, the near circular tracks may mean that the birds try to stay in light of a certain brightness corresponding to a certain distance from the tower. This implies that it may be productive to study the night vision of birds in the laboratory, to give the field observations a basis in physiology. And it now seems possible that strobing lights or lights of a color other than red might be safer for the small birds that come upon a huge metal structure in the night.

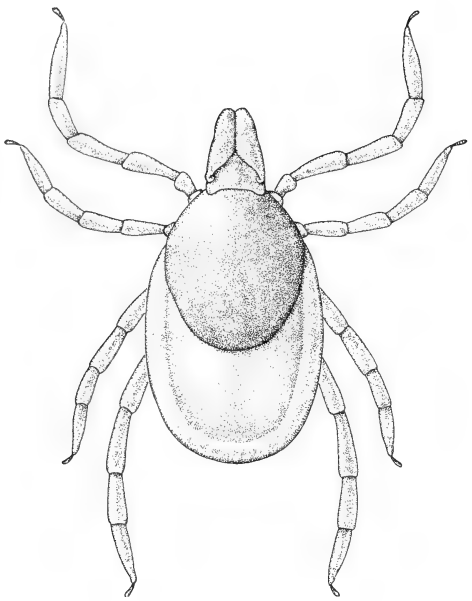
By *Ronald P. Larkin, Section of Wildlife Research*

New Tick in Illinois

On November 20 1987, Illinois Natural History Survey entomologist John K. Bouseman and Dr. Carl E. Kirkpatrick of the University of Illinois College of Veterinary Medicine searched for ticks on white-tailed deer brought by successful hunters to the Illlinois Department of Conservation check station in Jo Daviess County. Two deer were infested with single engorged females of the deer tick *Ixodes dammini.* These two records constituted the first for this species of tick in Illinois. The specimens were identified by Bouseman and his determinations were confirmed by Dr. James Keirans of the Smithsonian Institution, Washington, D. C.

Investigators in other areas have determined that the deer tick has a two-year life cycle. Tiny, six-legged larvae hatch from eggs deposited in the spring and attach to small mammals such as field mice or to birds for their first blood meal. After overwintering, the larvae molt into a second juvenile stage, the eight-legged nymph. The nymphs, which are about the size of a pinhead, attach to larger animals such as dogs, horses, deer, and to man for their second meal sometime during spring or summer. They then molt to the adult stage and attach again to large mammals, usually deer. They mate on this host and after another blood meal, the females drop off and lay their eggs.

The detection of *Ixodes dammini* in Il-



Female tick, *Ixodes dammini*, measures about 2.5 mm, roughly one-half to two-thirds the size of a dog tick (drawing by John P. Sherrod).

linois is of concern because the deer tick is the vector of Lyme disease, the number one tickborne disease in the United States. The disease is caused by infection with a bacterial agent, the spirochete *Borrelia burgdorferi*. The disease can result in chronic, sometimes debilitating illness resembling rheumatoid arthritis with symptoms ranging from acute headache to neurological impairment. Man can acquire Lyme disease when he enters wild areas during the warmer months of the year.

A team of researchers from the Illinois Natural History Survey and the University of Illinois College of Veterinary Medicine has begun a collaborative effort to determine the distribution of *Ixodes dammini* and *Borrelia burgdorferi* in Illinois. Readers of Survey Reports who might want to submit ticks for identification may send them in alcohol to John K. Bouseman, Section of Economic Entomology, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, Illinois 61820.

By *John K. Bouseman, Section of Economic Entomology; and Dr. Carl E. Kirkpatrick, College of Veterinary Medicine. Dr. Kirkpatrick is also an affiliate of the Survey's Section of Wildlife Research.*

Drought Stress and Plant Disease

Dry weather or lack of rain may have many adverse effects on plant health. Water normally moves into plant roots from the soil and is drawn upward through the vascular system by the tension that is created when evaporation occurs through small pores or stomates in leaf surfaces, a process called transpiration. Plants attempt to regulate water loss by opening and closing these stomates. On a summer day when transpiration rate is higher than water uptake by roots, stomates close early to limit water loss. Since roots continue to absorb water at night, the loss is replenished each day if soil moisture is adequate. When soil moisture becomes depleted during a drought, water tension in the plant increases until the plant becomes stressed. A mild stress may merely reduce photosynthesis and result in a slight yield reduction, while more severe stress may cause permanent damage to the plant. Plants weakened by stress often lose their ability to resist attack by disease organisms that rarely damage healthy plants.

Soybean plants inoculated with a root rot fungus after being subjected to controlled drought stress (photo by Don Schoeneweiss).

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Although the relationship between drought and disease is well known, few meaningful research articles have been published on the influence of drought on disease susceptibility. The lack of information is due to the difficulties encountered in trying to subject plants to drought stress under experimental conditions. Since it is nearly impossible to wet a soil to less than saturation, no good method has been developed to artificially adjust soil moisture to levels low enough to cause drought stress. The most common methods used in disease research have been to either withhold water until plants wilt, or to water at intervals of days or weeks so that plants alternate between stress and recovery. Neither method, however, is comparable to drought under field conditions, where plants become increasingly stressed over time with less and less recovery at night.

To overcome these difficulties, Survey plant pathologist D.F. Schoeneweiss constructed a series of stress chambers, based on a design developed for physiology research but modified for studies on stress/disease interaction. Plants are placed on top of a column of porous material and water stress is imposed by lowering the water level in the columns, thus creating a tension on the system. The stress chambers, made of PVC pipe, are placed inside a growth chamber so that the environmental factors, light, temperature, humidity, and soil moisture can be controlled and measured. Both soybean seedlings and rooted cuttings of woody plants have been maintained in these stress chambers for several weeks with normal, vigorous growth. The development of water stress in the plants is monitored at regular intervals with a diffusion porometer that measures stomatal resistance, and with leaf hygrometers that measure plant water potential or water tension in the plant.

Susceptibility of soybeans to a common and economically important root rot fungus did not increase under drought stress, contrary to reports in the literature that were based mainly on field observations. In contrast, a woody shrub species subjected to drought stress became susceptible to attack by a stem canker fungus, while nonstressed control plants remained resistant. Measurements of plant water stress confirmed that the stress chamber technique more closely simulates drought conditions in the field than any technique previously developed. This should enable researchers to obtain new information on how and why drought stress causes plants to become susceptible to certain diseases.

By *Don Schoeneweiss, Section of Botany and Plant Pathology*

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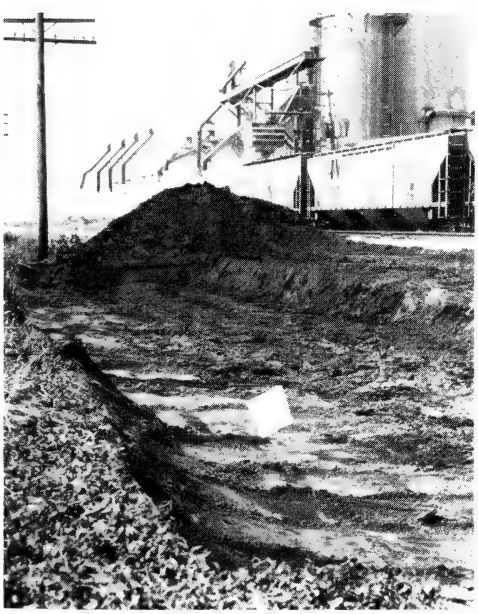
Cleaning Up Pesticide Waste in Soil

An estimated 1200 agrochemical retail facilities are scattered throughout the State of Illinois. Often, incidental spills of pesticides occur during mixing, loading, and clean-up operations, resulting in accumulation of hazardous concentrations of pesticides. The common methods of chemical waste disposal from contaminated sites are excavation and landfilling or on-site treatment to reduce residues to acceptable levels. Landfilling of pesticide waste is expensive because of high transportation and management costs, and space is quite limited. Furthermore, some chemicals may not degrade readily under landfill conditions, leading to the potential danger of ground water contamination by leaching. Indeed, pesticide wastes at agrochemical facilities may be responsible for high levels of herbicides that are sometimes detected in nearby wells.



Excavation of herbicide-contaminated soil at Galesville Chemical Company. The white flag in the foreground shows where a bulldozer started the excavation. The top 2 feet of soil were excavated and pushed into waste piles (background). Soil from one of the waste piles was spread over corn and soybean plots near by (photo by Allan Felsot).

On-site treatment methods involve spreading the contaminated materials over a surface and/or adding reagents or nutrients to accelerate physical, chemical, and microbiological degradative processes. The method of treatment depends on the physiochemical characteristics of the contaminants and their resistance to degradation.

Drs. Allan Felsot and Kudjo Dzantor of the Section of Economic Entomology, and Drs. Rex Liebl and Tom Bicki from the Department of Agronomy, have been investigating the feasibility of cleaning up herbicide waste by land application of contaminated soil at the Galesville Chemical Company, which is a fertilizer and pesticide application and retail operation in Piatt County. Soil along a railroad right-of-way had been highly contaminated with several herbicides during years of waste-water disposal.

After a state-of-the-art waste-water recycling facility was installed, the Illinois Environmental Protection Agency (IL EPA) required clean-up of the contaminated soil. With funding from the Illinois Hazardous Waste Research and Information Center, Dr. Felsot and his colleagues had the site excavated and backfilled with uncontaminated soil from the fencerow of an adjacent field. The contaminated soil was placed in large piles. The soil from these piles was spread over corn and soybean plots to determine if the herbicide waste would degrade by natural mechanisms. Crop phytotoxicity,

residues in soil and grain, and yield were monitored. Phytoxicity to soybean only was noted the the first year of the study but not during the second year. Parent herbicide residues were detected infrequently in corn, but levels were much lower than the legal tolerance established by the U.S. EPA. Herbicide residues degraded much slower in plots receiving soil from the waste piles than in soil receiving comparable doses of freshly sprayed herbicide, but after 2 years some degradation of the herbicide waste was noted. Herbicides remaining in the waste piles, however, did not seem to dissipate significantly after 2 years. The latter observation raises concerns about the validity of storing pesticide contaminated soil in landfills.

Land application of pesticide contaminated soil may be a viable and cost-effective alternative to landfilling, but caution must be used. The pesticides must be carefully identified and quantified to avoid application to sensitive crops. Presence of pesticide metabolites must be investigated in the harvested grain to ensure that total residues are not in violation of established tolerance levels. Finally, more research is needed to understand why high concentrations of pesticides in soil do not degrade as quickly as normally applied concentrations.

By *Allan Felsot, Section of Economic Entomology*

Control of Dutch Elm Disease in Illinois

Dutch elm disease (DED) is currently a problem in Illinois only in the greater Chicago area. The elms in the remainder of the State died earlier from DED or elm phloem necrosis. Elms, however, survived in Chicago suburbs that used disease control practices; and these elms, whether on city or private property, are greatly prized. The results of municipal efforts to control DED have been reported annually to pathologists at the Illinois Natural History Survey since 1955. Summaries of these results are published every 5 years and have proved useful to scientists and lay persons alike.

Dutch elm disease was found first in Illinois in 1950 in Coles County. By 1954 it had spread extensively through the southern half and the northeastern quarter of the State. By 1959 the disease had been confirmed by culture in every one of the 102 counties of Illinois and had killed 80 percent of the original elm populations in central and southern Illinois.

Community-wide control for DED began in 55 municipalities in northern Illinois in 1955 or 1956. The programs were based on two tactics: sanitation to remove the inoculum of the causal fungus and the sites for colonization by the insect vector and the spraying of healthy trees with an insecticide to protect against bark beetle feeding and transmission of the fungus. DDT was the applied insecticide. Thirty-seven of the cities maintained comprehensive disease control programs for 5 or more years. One city used methoxychlor as a substitute for DDT. Annual losses after 50 or more years in cities with programs were less than 1 percent of the original elm population.

By 1966, only 26 of the 37 cities were spraying with an insecticide, but 15 of the 26 were additionally using a soil sterilant to control root-graft transmission. Annual losses based on original parkway elm populations averaged from 0.9 to 1.4 percent for the 26 cities. Total elm losses in these cities through 1966 averaged 9 percent. In neighboring cities with incomplete or no programs, losses ranged from 81 to 94 percent.

By 1971, the switch from DDT to methoxychlor was complete; however, only 18 cities continued spraying. Since methoxychlor could be recommended only as a delayed dormant spring spray and since it was three times as expensive as DDT, many cities discontinued spraying for DED. Average annual DED losses between 1967 and 1971 for 26 reporting cities ranged from 1.8 to 4.4 percent, and total losses since 1955 for individual cities ranged from 10 to 37 percent of the elm population.

By 1976 losses in 13 cities that practiced sanitation and spraying could be compared with those of 11 cities that practiced sanitation. The advantage of a combined treatment between 1970 and

The picture above was taken in Urbana-Champaign in 1959; many diseased Dutch Elm trees were cut down because they couldn't be saved (photo by Dan Neely).

1976 on an annual loss basis was 0.9 percent (3.2 versus 4.1 percent). Average annual losses based on the original parkway populations for 24 cities between 1972 and 1976 ranged from 3.1 to 4.1 percent.

By 1982, 7 cities were spraying with methoxychlor and practicing sanitation; 14 cities were practicing sanitation alone. Based on the original parkway population, average annual losses in cities that practiced the dual treatment were reduced by 1 to 1.5 percent compared to losses in cities that practiced sanitation alone. Losses in both groups, however, declined from ± 4.4 to ± 2.4 percent during this period, and the economics of spraying came into question. In 1986 and 1987, only 4 and 2 cities, respectively, applied methoxychlor.

Control of DED in many suburban Chicago cities has been a success. The cities have maintained a mature tree population while replacing the limited number of elms lost each year. Aesthetic qualities have been maintained, but the control of DED has been a drain on municipal budgets. Cities without control programs spent a great sum in tree removal over a short period of time, and tree density in many of these cities remains low. Cities with control programs spent less per year initially but have continued their efforts for over 30 years. Those of us who highly value trees believe that both aesthetically and economically, the control efforts are worthy of continuation.

By *Dan Neely, Section of Botany and Plant Pathology*

Some Recent Survey Publications:

Jones, R.L., E.L. Ziegler, and H.C. Hanson. 1988. Mineral composition of feathers from Canada geese (*Branta canadensis*) fed experimental diets. Illinois Natural History Survey Biological Notes 128. 6 p.

Havera, Stephen P., and Glen W. Kruse. 1988. Distribution and abundance of winter populations of bald eagles in Illinois. Illinois Natural History Survey Biological Notes 129. 29 p.

Miliczky, Eugene R. 1988. Observations on the bionomics of the bee *Andrena* (*Tylandrena*) *erythrogaster* Ashmead (Hymenoptera:Andrenidae) with notes on *A.* (*Micandrena*) *personata* Robertson and *A.*(*Holandrena*) *c. cressonii* Robertson. Illinois Natural History Biological Notes 130. 18 p.

Swofford, David L., Michael R. Jeffords, and Karen W. O'Hayer. 1988. Predicting the susceptibility of Illinois forest stands to defoliation by the gypsy moth. Illinois Natural History Survey Biological Notes 131. 4 p.

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questionnaire

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SURVEY REPORTS

SEPTEMBER 1988, NO. 279

Sticky Attractant Traps For Monitoring Corn Rootworm Beetles

The *Diabrotica* beetles and their rootworm larvae are probably the most costly insect pests of agriculture in the United States. The combined attacks of the western corn rootworm, *D. virgifera virgifera*; the northern corn rootworm, *D. barberi*; and the southern corn rootworm, *D. undecimpunctata howardi*; cost Illinois farmers approximately 90 million dollars in control costs and crop damage annually. Heavy infestations of rootworms may cause an overall loss of 10–12 percent of corn production. In attempts to control larval damage to the root systems of corn, soil insecticides are routinely applied to 41 percent of the Illinois corn acreage. In addition, aerial sprays may also be applied to curb adult beetle damage to corn silks.

Control of these pests with annual applications of soil insecticides has become less dependable and more expensive over the past 35 years because of rootworm resistance to insecticides and accelerated microbial degradation of the insecticides in soils. Recent and widespread concern about ground water contamination by pesticides has stimulated increased interest in integrated pest management (IPM) practices for corn rootworms which are ecologically oriented and less dependent on chemical insecticides.

Crop rotations of corn and soybeans have generally provided a dependable method for minimizing corn rootworm larval damage. However, the production of continuous corn remains a popular agronomic option in some portions of the state. Therefore, the development of IPM strategies for corn rootworms has a high priority for reducing corn root-

Sticky trap without attractant, left, and trap with TIC attractant, right, both 30 minutes after placement along edge of cornfield in July 1988 (photos by Eli Levine).

worm damage and for decreasing agricultural production costs.

During the past several years, Drs. Eli Levine, Robert L. Metcalf, Richard L. Lampman, and Hassan Oloumi-Sadeghi of the Section of Economic Entomology of the Illinois Natural History Survey and the Department of Entomology at the University of Illinois have been investigating various monitoring techniques for corn rootworm populations. Accurate measurements are a necessary first step in planning and implementing IPM technology.

A simple and effective attractant trap has been developed by coating 16-ounce yellow plastic cups (Solo Cup Company, Urbana, Illinois) with an adhesive (Tangle-Trap) to form a cylindrical sticky trap. The coated traps are inverted over a developing corn ear or a 3–4 foot wooden stake placed on the edge of a cornfield. The reflectance spectrum of the yellow cup is excellent for attracting all three species of corn rootworm adults and therefore, these traps catch significantly more beetles than white or other colored traps. They are also more efficient and significantly less costly. The attractive efficiency of the yellow sticky cups was increased 10–20 times by using a small amount of chemical attractant (20–100 mg) applied to a dental wick on top of the trap.

We have developed an array of attractants, some of which are nearly specific for the individual species of corn rootworms, as well as several attractant mixtures based on the natural volatiles found in squash blossoms that are attractive to all three species of rootworm adults. Individual attractants, very attractive to the western corn rootworm, are p-methoxycinnamaldehyde (Chemical Dynamics Corporation, South Plainfield, New Jersey) and p-methoxycinnamonitrile (Aldrich Chemical Company, Milwaukee, Wisconsin). On the other hand, cinnamyl alcohol (Aldrich) and cinnamaldehyde (Aldrich) are exceptionally attractive to northern and southern corn rootworms, respectively. The most effective general attractant mixtures for all three species are TIC mixture consisting of equal parts of 1,2,4-trimethoxybenzene, indole, and cinnamaldehyde; and CI mixture consisting of equal parts of cinnamaldehyde and indole (all ingredients available from Aldrich). All of these specific attractant and attractant mixtures are effective in sticky traps at dosages as low as 20–100 mg and remain attractive for several weeks. We estimate the cost of the traps including attractant and labor for applying the sticky material at 30 cents each.

Three years of research experience in the use of these sticky traps has proven that they are effective and dependable tools for corn rootworm population monitoring. Such attractant sticky traps placed at corn-ear height have repeatedly collected substantial numbers of the several species of corn rootworms over 24 hours of trapping, even when populations are so low as to be undetectable by conventional plant counts (average number of beetles per corn plant have routinely been used to estimate population densities). These attractant sticky traps have an excellent future in corn rootworm population management programs where they could be used to predict which cornfields would need to be rotated back to soybeans or treated with a soil insecticide to prevent larval damage to the corn crop.

This research was supported by funding from the Illinois Department of Energy and Natural Resources and the Illinois Agricultural Experiment Station.

By *Eli Levine and Robert L. Metcalf, Section of Economic Entomology and the University of Illinois Department of Entomology, respectively*

Illinois Ants

Our planet abounds with life. Although some scientists continue to search the heavens for different forms of life, others continue to try and answer questions concerning the flora and fauna of this planet. Basic questions are, what kind of animal is it? Or, where is it found? This is the emphasis of a recent publication by Mark DuBois and W. E. LaBerge listing the ants of Illinois.

Although ants are only one small group of insects, they are extremely abundant and readily encountered by city dweller and farmer. Many colonies in Illinois contain several thousand workers (all females). Some Illinois ants raid other ant colonies for food, while others harvest fungus to feed their young.

Photograph of ant hill housing *Formica exsectoides* taken last winter on Route 9, near Tremont, Illinois (photo by Mark DuBois).

Although there are more kinds of ants than kinds of birds, new species are being discovered continually. Centers of diversity are located in the tropics; however, much work still needs to be done in temperate regions where there are poorer faunas. For example, army ants are viewed as tropical, but two species have been discovered in the southern part of Illinois. A third species may be found in the state, since it is already known from Iowa and Missouri.

A thorough examination of the collections of the Survey combined with knowledge gained in the field over the past six years is the basis for this article. Where appropriate, names of ants were updated to reflect current views of the classification of ants. In Illinois, a total of 121 different kinds of ants has been reported. Of these, 95 species are native (and are found in the Survey collection), 5 are introduced, and the rest have been reported only in past literature. A total of eight new species has been described from Illinois. The last three of these were described in 1934. Basic distributional information (known county records listed for each species) and habitat information gleaned from fieldwork in Illinois are included in the list.

With this knowledge, distribution of ant species across Illinois counties is understood more clearly. The next step is a review of the extensive soil, leaf litter, and rotten wood samples housed at the Survey. Most of these collections were made using Berlese funnels to concentrate animals found in the above materials. Collections have been made throughout the state (and surrounding states) for a number of years. Unfortunately, the material must be sorted before it can be identified and used. Many of the vials are filled with leaf fragments and soil in addition to animals, and they are being reviewed for any ants contained in them. Additionally, fresh samples are being obtained and examined. Comparisons may shed some light on changes in distribution which may have occurred in the past 30 or 40 years. New information may also be discovered since many ant species live deep within the soil (or rotten wood) and are rarely encountered.

The end result of these efforts is that we continue to increase our knowledge by small amounts and establish a solid base for future work. While the search continues for life in the heavens, we now know a little more about life on earth, even the life under Illinois sidewalks.

By *W. E. LaBerge, Head, and Mark DuBois, both of the Section of Faunistic Surveys and Insect Identification*

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Recent Publications Available

A new publications list that includes all publications of the Illinois Natural History Survey, 1876–1988, and out-of-house publications by the INHS staff, 1983–1988, is now available.

Voegtlin, D. J., and C. A. Bridges. 1988. Catalog of the Cinara species of North America (Homoptera:Aphididae). Special Publication 8. 55 p.

The intent of the authors was a thorough annotation of papers in the catalog so that researchers could quickly identify those that contain information on the species they are studying. The annotations make clear which forms of the aphid are discussed in a given paper and what other information can be found there. The senior author is responsible for the collection and annotation of the literature. The junior author provided the computer expertise and programs used to create this catalog.

Bellrose, F. C., S. P. Havera, F. L. Paveglio, Jr., and D. W. Steffeck. 1983. The fate of lakes in the Illinois River valley. Biological Notes 119. 27 p.

The demand for copies of this publication made a second printing necessary. The reprint is now available.

Requests for these free publications should be sent to Chief Lorin I. Nevling, Illinois Natural History Survey, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820.

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Southwestern Caddisflies Collection Donated to the Survey

After over 12 years of collecting in Arizona and the southwest, Dr. Milton W. Sanderson has deposited his extensive caddisfly material in the scientific collections of the Survey and his field and professional journals (1938–1983) in the archives of the Survey library. He remains active today, having focused his research interests on the wildflowers of New Mexico.

In 1975, Dr. Sanderson retired to Arizona after 33 years of service with the Section of Faunistic Surveys and Insect Identification. After the publication of two classic monographs on the Elmidae or riffle beetles early in his career, Dr. Sanderson worked most of his professional life with terrestrial insects, particularly the systematics of Coleoptera (especially Scarabaeidae, Pselaphidae, and Staphylinidae). In retirement he returned to that early fascination with aquatic insects.

He completed a chapter on aquatic and semiaquatic Heteroptera, published in the Aquatic Insects and Oligochaetes of North and South Carolina (Brigham, Brigham, and Gnilka 1982); made significant contributions to the knowledge of the southwestern Ephemeroptera (mayflies), Plecoptera (stoneflies), aquatic and semiaquatic Heteroptera (true bugs), and Elmidae; contributed to the awareness of rare, threatened, and endangered species in Arizona; and accepted an appointment at Northern Arizona University. He eventually centered his attention upon the Trichoptera, or caddisfies—a wonderfully diverse group of aquatic insects.

The M. W. Sanderson caddisfly collection contains approximately 100,000 specimens of larvae, pupae, and adults,

MILTON W. SANDERSON

and documents 16 of the 19 North American families of caddisflies as occurring in Arizona. It is particularly valuable because of the intensity of collecting effort for one geographic area. For example, hundreds of collections from at least 20 sites along Oak Creek from source to mouth between 1975 and 1987 document all seasons and elevations to establish emergence periods, flight periodicities, and other life history and ecological information.

The Oak Creek Canyon area, located between Flagstaff and Sedona in north-central Arizona, in effect became his new laboratory. Although Dr. Sanderson collected hundreds of blacklight trap, sweep, and hand-picked samples throughout Arizona between 1975 and 1987, he remained particularly captivated by the diverse fauna of Oak Creek, sampling it intensively for over 10 years.

Oak Creek originates in the canyon and flows 43 miles to its convergence with the Verde River. This river represents a major transitional area in North America, reflecting important faunal changes from source to mouth. Within Oak Creek, species of caddisflies found in the upper stream reaches at higher elevations typically represent North American faunal elements. These gradually give way at lower elevations to genera and species more characteristic of the Neotropics.

From his long association with Dr. Herbert H. Ross and the Survey, it was understandable that Dr. Sanderson would wish to deposit his caddisfly collection here. The Survey's material, gathered by Ross and his students over many years, constitutes the foremost collection of this order in the Western Hemisphere and is one of the best known and most heavily utilized collections at the Survey. The specimens document two classic papers: a faunistic report on caddisflies (Ross 1944) and a book on the evolution of montane caddisflies (Ross 1956), as well as many other important systematic papers by Ross and his students. Also included is the L. J. Milne collection, deposited at the Survey in 1940. The richness of type specimens is one of the outstanding features of the Survey's holdings of caddisflies. Approximately 600 primary types and over 1,000 paratype specimens, representing worldwide species, are deposited in the collection.

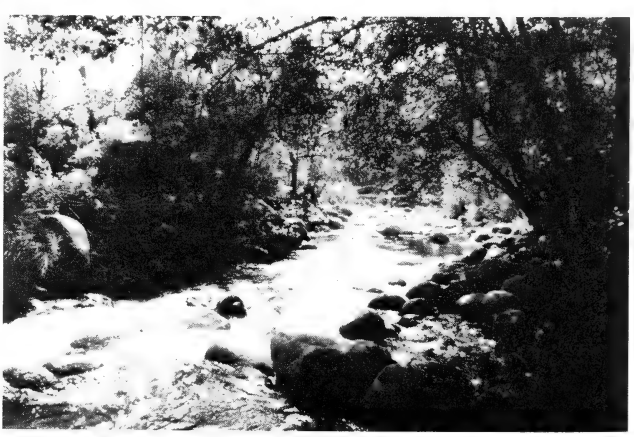
Among the caddisflies, Dr. Sanderson developed a special interest in the hydroptilid genus Ochrotrichia, assembling one of the most comprehensive collections in North America. He also maintained an active exchange program with other caddisfly specialists and collectors throughout the United States and Mexico so that the collection contains sizeable numbers of non-Arizona species. This material adds a substantial number of species and localities to the Survey's collection, enriching our holdings in other geographic areas, especially Arizona, Texas, and the southwest.

The preliminary checklist of caddisflies of Arizona approaches 200 species. For comparison, Illinois has about 250 species and one of the most diverse faunas (ca 330 species) occurs in the Carolinas. Although Arizona has more limited aquatic habitats when compared to the midwest or the southern Appalachians, its caddisfly fauna is rich and diverse, combining both North American and Neotropical faunal elements.

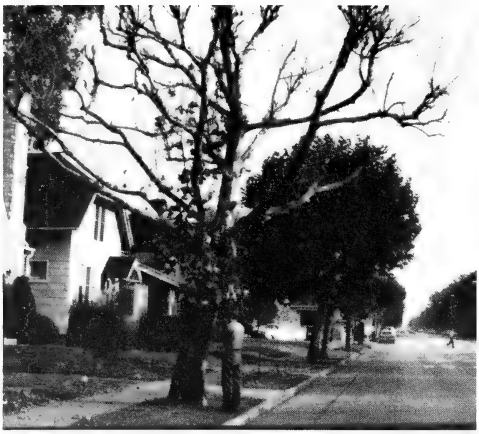
By *Allison Brigham and John Unzicker, Section of Faunistic Surveys and Insect Identification*

Systemic Chemical Control of the Sycamore Anthracnose Disease

The sycamore is a fast-growing tree and easily transplanted. During the past 30 to 40 years the American sycamore has frequently been planted on private and public property to develop shade quickly. Unfortunately, it is often afflicted with a destructive fungus disease



Oak Creek in Arizona, a part of the 43-mile area where Dr. Sanderson did most of his collecting of caddisflies (photo by Allison Brigham).



Sycamore anthracnose frequently causes severe defoliation and twig dieback in the growing season. This type of disease symptom is sometimes confused with frost damage (photo by Eugene B. Himelick).

Trunk injection of a relatively large volume of the systemic fungicide, Arbotect, is possible using a plastic bottle system and a series of connections into the sapwood of each tree (photo by Eugene B. Himelick).

known as sycamore anthracnose. The disease is severe in about one of every three years, and affected trees sometimes remain virtually leafless throughout late spring and early summer.

American sycamore has adapted well to adverse growing conditions and survives the anthracnose disease through its remarkable ability to recover, even though both twigs and leaves are killed. By early July, severely affected trees may be refoliated for the remainder of the summer. Trees that are genetically more susceptible to this disease suffer with repeated twig dieback and defoliation and develop a contorted and very unsightly appearance.

Since spraying costs are high and chemical control is often poor, very little effort has been made to reduce disease incidence in urban-grown sycamore trees. Field research has been carried out at the Survey to develop control measures that could replace the aerial sprays. Such tests must be done for several years to determine the effectiveness of control. Field tests using Arbotect 20-S injected into the trunks of American sycamores in 1979 provided excellent-to-good control of anthracnose. For good control, the systemic fungicide had to be injected in the fall at least six months before the disease became evident the following spring.

To control the disease, additional field tests were conducted in 1986, 1987, and 1988. Arbotect 20-S injected into sycamore trees in September 1986 gave good control of both the leaf and twig blight stages of the disease in 1987 and 1988. On untreated trees, the amount of defoliation and infected leaf tissue continued to increase. On treated trees, infected leaves remained intact and showed little increase of infected tissue. Some reduction in powdery mildew on leaves was also evident on treated trees.

A single fall injection of Arbotect 20-S in 1979 gave good control of the disease for three growing seasons. The second field trial in the fall of 1986 has given good control for two growing seasons. The American sycamore should not be planted in residential areas; it is best grown in large parks and in undisturbed forested areas. In an urban environment, the sycamore becomes a large tree and causes high lawn maintenance through the constant raking of leaves, twigs, and trunk bark. Sycamores are relatively long-lived—50 to 100 years. Until disease-resistant sycamore varieties are developed, the use of a systemic chemical injected into the tree is the best control known for sycamore anthracnose. Additional information can be obtained by contacting your county farm advisor or a commercial arborist experienced and trained in tree-injection work.

By *Eugene B. Himelick and R. Dan Neely, Section of Botany and Plant Pathology*

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After more than a century and a quarter of distributing our publications at no charge and faced with serious and growing financial constraints, the Survey is implementing a pricing schedule to recover a portion of the costs of distribution. We greatly appreciate the interest shown by our readers in the past and trust that they will continue to find our publications an outstanding value.

Lorin I. Nevling, Chief

The following pricing schedule was initiated on October 15, 1988:

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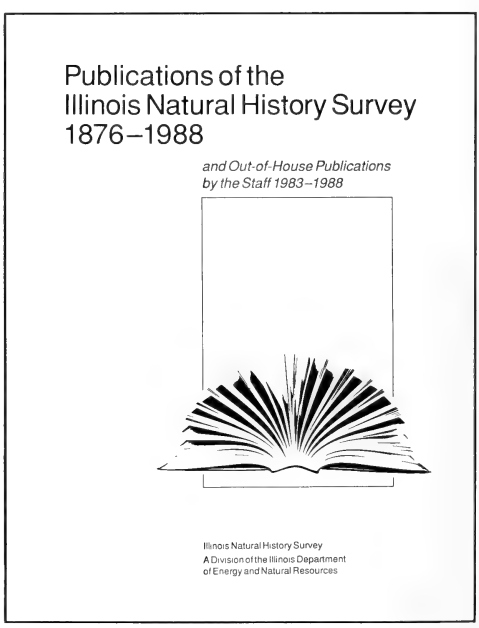

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The Illinois
NATURAL HISTORY SURVEY REPORTS

NOVEMBER-DECEMBER 1988 NOS. 281-285

Illinois Geographic Information System

Geographic Information Systems are having an impact across broad areas of government and business. Only recently have they found application within the research community. These applications have grown to such an extent they warrant this special issue of *Illinois Natural History Survey Reports*.

A Geographic Information System, or GIS, is a computer-based system for automating, manipulating, and displaying mapped information. GIS, in the broadest sense, consists of the computer itself (hardware), terminals and plotters (peripherals), automated maps and associated data (coverages and attribute data), and programs that tell the computer how to perform the required tasks (software). GIS technology is relatively new even to the computer world, and the oldest systems are not much more than 10 years old. The Illinois Department of Energy and Natural Resources established the Illinois GIS as part of the Lands Unsuitable for Mining Program (LUMP) about 6 years ago. At that time the system was used principally by the three scientific Surveys of the state (Geological, Natural History, and Water), the State Museum, and the Division of Energy and Environmental Affairs for LUMP-related tasks. GIS has grown considerably since then and currently supports a user community of more than 300 in a variety of applied and basic research projects. These introductory paragraphs describe the hardware, software, and database which form the Illinois GIS.

Hardware. The Illinois GIS had its beginning on a PRIME 750 minicomputer supporting about a dozen users. Since the original database was small, a total of 600 megabytes of disk space was adequate for on-line storage (1 megabyte, or Mb, of information represents approximately 330 pages of single-spaced text). Data input was from keyboard (text and tabular data) or digitizer (map data). Output was from color or monochrome graphic terminals or if hard copy was required, by line printer (text) or pen plotter or camera recorder (maps).

The user community has expanded by a factor of thirty. Impact upon the system has been largely in four areas. Each of these, and their resolutions, are discussed below. First, there has been impact upon the computer itself. This problem was first "solved" by acquiring a larger computer, a PRIME 9955 superminicomputer, with a capacity approximately three times that of the original system. The original PRIME 750 was retained, and both computers were linked into a network that shares data and software as a pool available to all users. Subsequently, a PRIME 9650 computer was added to meet the special needs of the Hazardous Waste Research and Information Center. Within the last 6 months, a fourth computer, a PRIME 2655, was added to facilitate communication and provide additional support for users in Springfield. Second, the database has expanded at an astonishing rate. The original disk storage (600 Mb) has been expanded to almost 12,000 Mb, with an additional 1,700 Mb under consideration for purchase. Third, there has been a continuing demand for additional and more sophisticated peripheral devices. On one hand, this need has been met simply by purchasing additional terminals. Advanced users, however, have elected to acquire sophisticated microcomputer workstations. Specialized peripherals also have increased in number, with the GIS now supporting three camera

recorders, eight large-format plotters, and nine digitizers. Finally, the need for additional and enhanced communication grows as more users come on line or desire communications with other computers. This need has been met by providing a variety of dial-in options (including a toll-free number), direct hardwired connections to other local computers, and links to national and international computer networks.

Software. The heart of the Illinois GIS is the ARC/INFO software package developed and maintained by Environmental Systems Research Institute of Redlands, California. This package was selected from similar vendor packages by analyzing the goals and objectives of the Illinois LUMP. This analysis included consideration of necessary data sets, data manipulations, required deliverables, cost, and the all-important timetable. ARC/INFO was the single package that met all selection criteria.

Enhancements to the basic ARC/INFO software package have been responsive to the expanding needs of the user community. In areas where other commercial software already exists to perform these tasks, links between ARC/INFO and these other software packages have been provided by Environmental Systems Research Institute, typically in the form of commands that permit the import or export of data files (other software vendors provide similar commands within their software). The ARC/INFO package itself has grown to a family of software with subsystems for specialized applications such as NETWORK, providing enhanced capabilities for manipulating data for road or stream systems, and TIN (Triangulated Irregular Network), for displaying and modelling 3-dimensional data and/or surface features.

A significant recent expansion to the GIS software has been the integration of ERDAS image-processing software (previously limited to running on a personal computer) with ARC/INFO. It was purchased from ERDAS, Inc. in Atlanta, Georgia, and allows processing of satellite-collected data (e.g., Landsat) and raster GIS analysis. The Environmental Systems Research Institute and ERDAS, Inc. have cooperated to provide import and export communications between the two systems, including polygon-raster conversions.

Database. Spatial data are of three types: points, lines, and polygons. Points represent position only and have no dimension. An example of a point coverage is the locations of all weather stations in Illinois. Line data represent both position and dimension. In the simplest case, a line runs between two points, but lines can play connect-the-dots to form complex data sets. An example of a line coverage is the road and highway network of the state. Polygon data describe areas. The simplest polygon is a triangle, which can be described by just three points, its corners. Polygons typically are very much more complex. An example of a polygon coverage is the land cover of the state. Some areas are urban, some forested, some lakes or other wetlands, some prairie, some in row or field crops, and some in pasture. This last example demonstrates the other significant element of data in a GIS. Attributes are tied to mapped features. Thus, we not only know where points, lines, and/or polygons are (location), but we can describe them (attributes). The topology of the highway map looks like spaghetti. Attribute data let us sort interstates from United States and state highways, two-lane from four-lane roads, concrete from gravel surfaces, etc.

The original concept for the Illinois GIS called for three databases. This design has been followed with little modification and, based upon observations of databases in other states, appears to be both unique and an important asset. One of the charges within LUMP was to provide regional perspective to natural resource, energy supply, and socioeconomic issues. This was accomplished with a statewide database of nearly 100 parameters spanning all relevant data categories. Examples include the 1980 census, land cover, soils, surface and groundwater hydrology, zip code districts, bedrock geology, quaternary materials, roads, railroads, pipelines, transmission lines, wetlands, natural areas, administrative

boundaries, etc. Minimum resolution for polygons varied from 20 acres to 1-square mile but, in general, was fairly coarse. The coverage, however, was complete for all of Illinois.

The second and more detailed database concentrated upon those portions of Illinois where coal mining was most active: principally a band across the southern counties and a large area in the west-central part of the state. This database contained many of the same parameters found in the statewide database, but at a much higher level of resolution; here, typically 3 to 10 acres as minimum polygon size.

The third and most detailed database was envisioned as a piecemeal affair, perhaps never to be completed, but to be assembled on a project-by-project basis, with users of the GIS automating best-available data as needed. Some of these projects involve many different data sets for a small area (such as the work being done for specific mine permit application areas). Conversely, others involve a single data set covering a large area (such as the Illinois component of the National Wetlands Inventory being conducted jointly with the Illinois Department of Conservation and the U.S. Fish and Wildlife Service). Resolution typically runs to fractions of an acre in the detailed database.

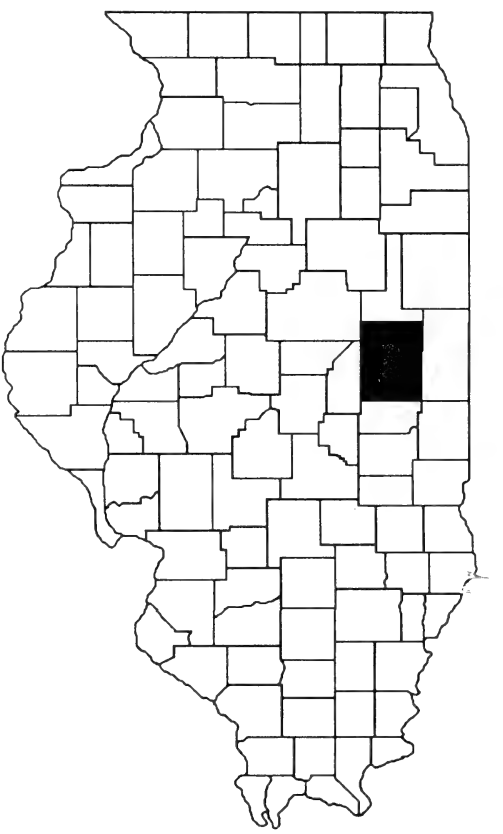
The obvious direction in database development may be summed up in two words. The first is "more." The second is "better." Perhaps a less obvious trend is the change in the sources of these data. Five years ago Illinois started out automating data from paper maps developed by conventional means. Certainly some of the data received today still comes in this form, but the bulk of data is on magnetic tape, and much of this originated in digital form from remote sensing data sources.

This thumbnail sketch was designed to provide you with an outline of the toolbox we call the Illinois GIS. The presentations that follow should give you some idea how these tools work.

By *Warren Brigham, Manager for Natural Resources, Illinois Geographic Information System*

GIS at the Natural History Survey: On Fish . . .

In the late 1800s, Survey scientist Stephen A. Forbes and colleague Robert Richardson sampled stream fish populations from 48 different locations in Champaign County, Illinois, while gathering material for their publication *The Fishes of Illinois*. Approximately 30 years later, David Thompson and Francis Hunt of the Natural History Survey expanded efforts within the county, sampling fish from 132 different stream locations. Comparisons of these collections resulted in one of the first rudimentary documentations of large-scale changes in fish species distribution over a 30-year period. Recognizing the unique opportunity to document changes in stream fish populations following 60 years of landscape alterations and human development, Survey scientists R. Weldon Larimore and Phillip Smith revisited the same sites sampled 30 years earlier by



Champaign County, located in east-central Illinois.

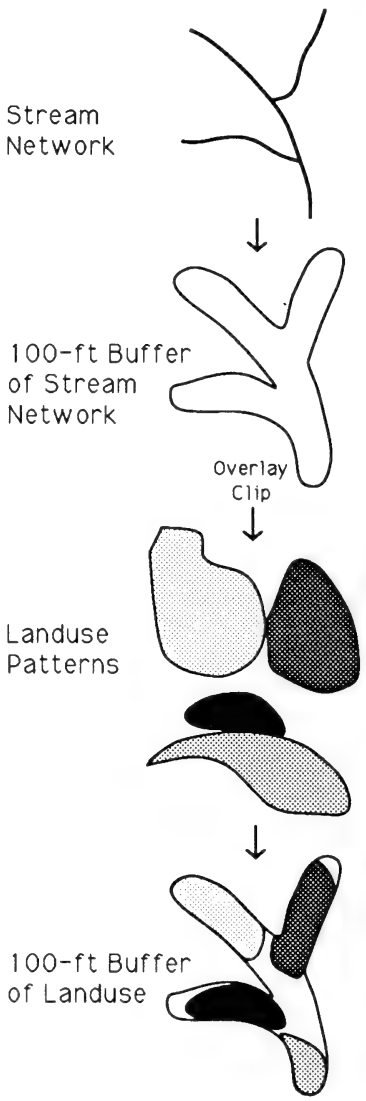
Thompson and Hunt. In addition to fish collections, Larimore and Smith also recorded baseline instream habitat and land-use information in the vicinity of each sampling site.

Over the past 30 years, additional changes that could dramatically influence fish populations have occurred in each of the six river basins within Champaign County. These include the installation or upgrade of sewage treatment facililties, a greater use of pesticides and chemical fertilizers, and increased urban development. Merely documenting changes in the proportions of species does not indicate why changes may have occurred in fish populations, and therefore limits the capacity to extrapolate findings to other parts of the state. The 1959 land-use and habitat information, in conjunction with the extensive fish collections, provides a baseline from which to begin assessment of the regional effects of human activities on fish populations.

For the past one and one-half years, staff of the Aquatic Biology Section led by Lewis Osborne, R. Weldon Larimore, and Peter Bayley, and funded by the U.S. Fish and Wildlife Service, Sports Fish Restoration Program (Project F-76-R), have been revisiting the 1929 and 1959 Champaign County sampling sites. In addition to repeating the quantitative fish survey and assessing 90-year distributional trends, these investigators have been collecting detailed information on fish food supply, instream and riparian physical habitat conditions, and land use. Integration and synthesis of these extensive land-use/land-cover, habitat, and biological databases necessitate the use of analytical computers and sophisticated software.

The Illinois GIS provides these researchers with the capability to determine not only the size of the individual station drainage areas but also the total area of each land-use type within each drainage. The GIS software determines the area of each land use within a drainage basin and outputs this information to a separate data file. This land-use data file is merged with the biological data file permitting assessment of the relationships between land uses in the watershed and fish community structure. Such relationships are extremely important to resource managers and planners, but have rarely been available prior to the development of GIS due to the exhorbitant amount of time that would be required to determine the individual areas by hand.

An additional capability provided by the GIS and not available to previous researchers is the "buffer" facility. The buffering facility allows researchers to incorporate into their analyses only the



Representation of the ARC/INFO "buffer" facility used within the Fishes of Champaign County Study.

land occurring within a designated distance from the stream channel. Essentially, the buffer facility creates a boundary around a selected stream channel. The distance of the boundary border from the stream channel is established by the user. This buffered file is used to overlay and cut, in a manner similar to a cookie cutter, the watershed land-use file, resulting in a file containing only the land uses within a designated distance from the stream channel. The areas of each of the land-use types within this buffered coverage can then be merged and analyzed with the biological data files.

Possibly the most important capability provided by the GIS is its ability to quantify present-day land-use conditions within a study area and store them in a form that is readily available and retrievable.

By *Lewis Osborne, Head, Aquatic Biology Section*

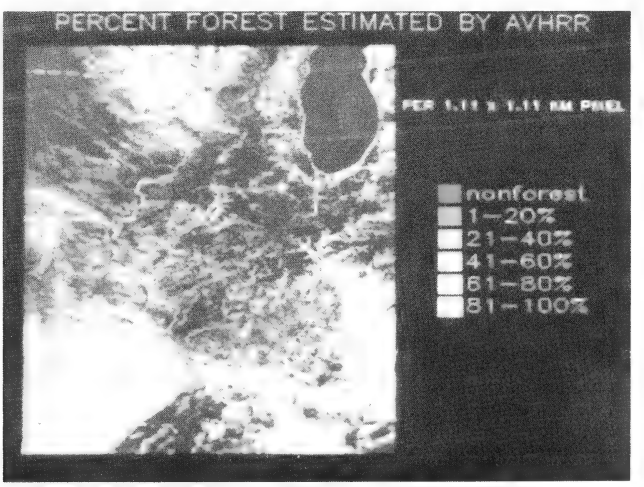
On Estimating Regional Forest Cover . . .

Satellite imagery, designed to provide information about the Earth's surface, has been proven extremely valuable for monitoring forests and other natural resources and for predicting future trends. An overview of the spectral and spatial attributes of U.S. satellite data was given in the article "Can the Productivity of Forests Be Estimated from Space?" in the January 1988 (No. 273) issue of *Illinois Natural History Survey Reports.*

Applications of satellite imagery vary in part due to the spatial resolution of the data. The Landsat Thematic Mapper (TM) sensor resolves features on the ground less than 0.1 hectare in size (30×30 m). TM applications include land-cover mapping, detection of land-cover change over time, and quantitative vegetation analyses over relatively small regions. The use of TM data for studying large areas, such as multi-state regions, is generally not practical because of the volume of data that would need to be stored and processed. In contrast, Advanced Very High Resolution Radiometer (AVHRR) imagery has a minimum resolution of about 123.2 hectares (1.1×1.1 km) and is used to provide similar, but coarser information over considerably larger regions than TM data.

The utility of satellite data is greatly enhanced by combining them with other landscape variables in a GIS. For example, soils, slope, and satellite-derived land-cover data can be integrated in a GIS to model erosion potential. Satellite data can be an efficient means of acquiring or updating land-cover information in a GIS because they are available in digital form, thus eliminating the need for manual data entry.

Although combining remote sensing and GIS techniques are well-established procedures, researchers at the Survey, in conjunction with colleagues at Oak Ridge National Laboratory and the University of Illinois, were among the first to use multiple layers of satellite data at



Forest cover estimates as predicted by the AVHRR data.

varying resolution along with other landscape variables in a GIS. Nesting coarse resolution AVHRR data with a sample of high resolution TM data allowed researchers to maximize the advantages of both types of data in an important study concerning estimation of deciduous forest cover and productivity over large areas.

Estimating the spatial pattern and productivity of forests over large areas is important to addressing many of today's pressing environmental concerns. Forests cover approximately 2.5 $\times 10^9$ hectares of the Earth's surface and are a dominant feature of the global carbon and hydrological cycles. However, vast amounts of forestland, especially in the tropics, are being converted to other land uses, contributing to a rise in the atmospheric carbon dioxide and the potential for global warming from the "greenhouse effect." AVHRR data have the most useful combination of spectral and spatial resolution for assessing vegetation over very large regions. However, two factors hamper the assessment of deciduous forest cover and productivity from AVHRR data. First of all, forest cover and productivity often occur in a finer pattern than the resolution of the AVHRR data, creating pixels (minimum units of data) of mixed information. Such mixed pixels are difficult to interpret without additional information. Secondly, ground-collected data pertaining to forest cover and productivity typically cover small plots that do not relate easily to the large, diverse AVHRR pixels. To circumvent these problems, Survey researchers used the higher resolution TM data to calibrate, and thus extend, information available from the AVHRR data.

For forest cover estimation, Jackson County, Illinois, was one area used as a calibration center. TM data were classified to determine percent forest cover. AVHRR and TM data were precisely aligned and subset to equal areal coverage. A sample of pixels containing AVHRR spectral values and the TM percent forest cover information was extracted via GIS techniques. Regression analysis was used to relate the percent forest cover determined from TM data to the AVHRR spectral information.

The regression equation that best predicted forest cover from the AVHRR spectral values (a two-variable model using bands 1 and 2) was applied to each forested or partially forested pixel of an AVHRR data set centered on Illinois, covering over 560,000 square kilometers of 428 counties in 10 states. Using the GIS to overlay county boundaries, these data were aggregated into an average percent forest cover estimate for each county. The AVHRR-estimated percent forest cover over the entire region was 19.6 percent.

Validation of these estimates was critical to assessing the significance of the project methodology. U.S. Forest Service estimates of county forest cover were available for validation purposes. The data ranged in age from 1966 to 1988 and represented many years of field work. Correlation analysis revealed a highly significant relationship between the AVHRR and Forest Service estimates, with $r=0.89$ overall ($p<0.0001$). The strong correlation indicates that the technique provided reasonably accurate estimates of forest cover over a large region, and at very low cost relative to conventional methods.

The potential value of this technique is very exciting. With an extensive network of calibration centers, global forest-cover estimates could be accomplished with minimal expense. Monitoring global vegetation change could help direct better management of our global biospheric and atmospheric resources.

By *Elizabeth A. Cook and Louis R. Iverson, Botany and Plant Pathology Section*

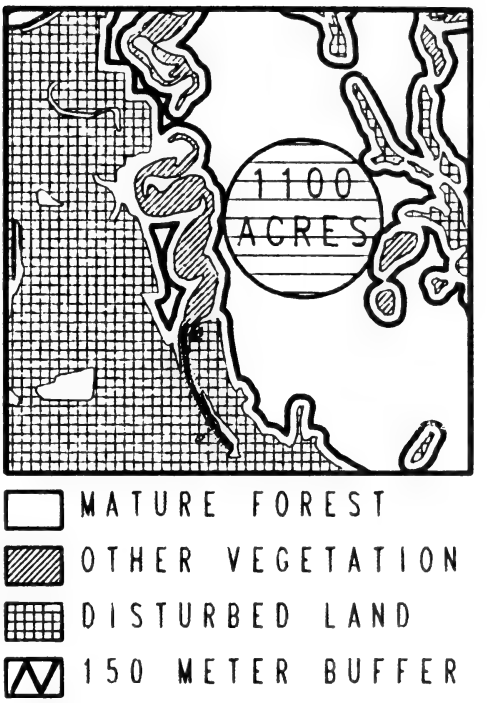
On Shawnee National Forest . . .

The Survey has been using the GIS to assist biologists and foresters in analyzing forest resources for a long-term management program for Shawnee National Forest. The 851,000-acre forest in southern Illinois consists mostly of small tracts of land with a wide range of vegetative cover types, and thus presents special problems in resource management. In order to allocate land for

such varied uses as wildlife habitat, recreation, and timber harvesting, it is necessary to characterize the requirements for each use and then to identify tracts most suited to a given use.

One of the goals of the Shawnee management plan is to identify and protect large tracts of mature forest habitat required by some avian wildlife species, such as the Kentucky warbler. In order to successfully reproduce, this interior forest species requires a habitat that is separated from more open land covers such as tilled fields or cleared timber tracts. The warbler is an indicator species whose presence is used in determining extent of forest habitat disturbance. A list of the parameters that define the habitat requirements for area-sensitive species such as the Kentucky warbler was compiled by representatives from the Forest Service, the Illinois Department of Conservation, the Illinois Chapter of the Audubon Society, and the Nature Conservancy. Suitable forest stands for management of forest interior species were determined to require a minimum of 1,100 acres, and to consist of trees greater than 30 feet tall with a canopy cover of at least 30 percent. Ninety percent of any selected tract must be in Forest Service ownership. Other land covers that would result in conditions detrimental to nesting or feeding by the indicator species need to be separated from the selected tract by a 150-meter zone. In addition, the ideal tract will be as close as possible to a circle in shape in order to minimize predation by undesirable open-area species, such as the cowbird.

Using the Coal-Area Database, which contains detailed information on land cover as well as coal resources, areas within the National Forest were selected that meet the minimum values of each of the habitat parameters as listed above. Nineteen 8-color map sheets were produced that cover about two-thirds of the total forest acreage. These maps will enable forest planners to identify forested tracts that should be preserved for interior species habitat. In order to allow for maximum flexibility in selecting the most suitable forest tracts, a circle of



Portion of Wolf Lake Quadrangle, Union County, showing land cover and potential 1,100-acre tract for interior species management plan.

1,100 acres (the critical areal extent for the desired habitat) was generated using the computer. The circle is plotted on semi-transparent medium so that the planners can slide it over the map. This technique enables the user to locate those potential areas which are most circular in shape and also to evaluate adjacent land use/land cover that might enhance or conflict with the proposed management plan.

Future collaboration between the Survey and Shawnee National Forest may include computer-aided analysis of management alternatives for other uses of forest resources.

By *Katherine J. Hunter, Faunistic Surveys and Insect Identification Section*

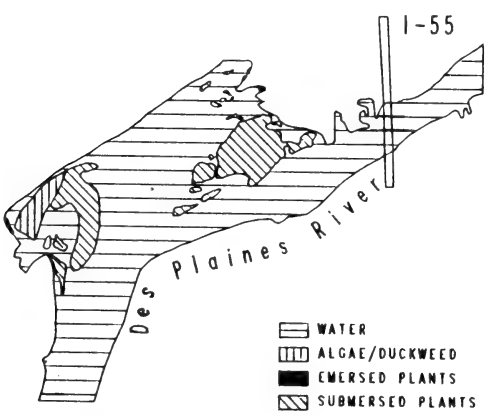
On Aquatic Plants . . .

Aquatic plants are key components of a healthy aquatic system. They dampen wind- and boat-generated waves and stabilize bottom substrates, keeping the water clear for sight-feeding gamefish,

herons, and egrets. The plants are a direct food source for some waterfowl and an indirect source, via detritus pathways, for many aquatic invertebrates, which in turn serve as food for both fish and waterfowl. Plants shelter some organisms and serve as spawning areas for others. Ammonia, which is toxic to aquatic animals, is taken up as a nutrient by aquatic plants.

Submersed and floating-leaved aquatic plants flourished in the Illinois River and its backwaters until the early 1960s when submersed plants and all but one species of floating-leaved plants disappeared along a 200-mile reach stretching from Starved Rock to Grafton. Aquatic vegetation remained in the upper Illinois River from Starved Rock Dam to the beginning of the river at the confluence of the Kankakee and Des Plaines rivers. The lower portion of the Des Plaines, part of the Illinois Waterway, links Lake Michigan to the Mississippi River. This reach was virtually devoid of aquatic plants, probably due to urban pollution from the Chicago-Joliet area. The aquatic plants in the lower Illinois River were affected by a different problem, erosion silt, which reduced light penetration and settled into an unstable, floculent sediment, unsuitable as rooting substrate for most aquatic plants.

Recently, aquatic plants have reappeared in the upper reaches of the Illinois Waterway. In 1985 we began to document habitat quality in the lower Des Plaines River (river mile 273–286) by (1) characterizing the status of aquatic macrophyte and macroinvertebrate communities and (2) assessing factors that may limit aquatic life, including habitat characteristics, sediment toxicity, and boat traffic. Low-altitude, natural color aerial photographs were used to determine the extent and location of submersed and emersed vegetation beds. Aerial photograph interpretation and groundtruth survey data were integrated and recorded on base maps (7.5 minute U.S. Geological Survey quadrangle maps), digitized, and entered into the GIS using ARC/INFO. INFO was used to calculate aerial coverage of vegetation beds and habitat classes, and the ARC system was used to produce vegetation maps.



A vegetation map for a segment of the Des Plaines River between river miles 277 and 278.

Results showed that 23 species of aquatic macrophytes occupied nearly 60 hectares (148 acres) in the lower Des Plaines River between Brandon Road Lock and Dam and the confluence of the Des Plaines and the Kankakee rivers. Although some areas remain devoid of vegetation, most main-channel border and side channel areas are now vegetated.

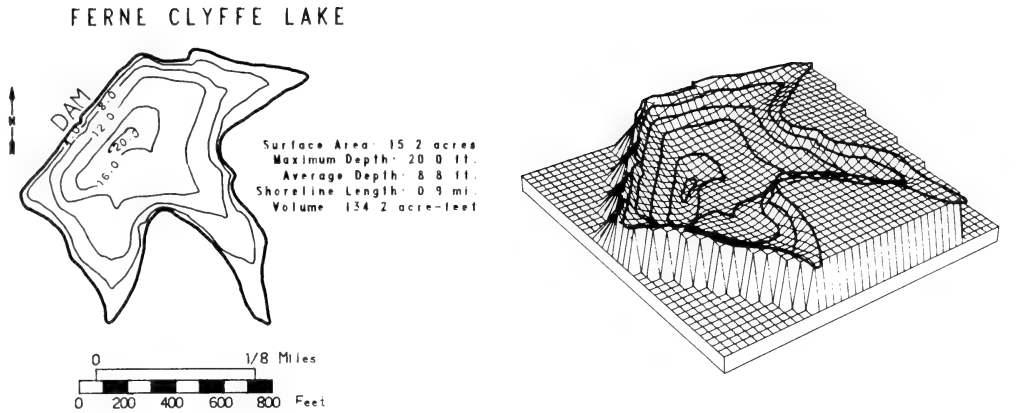
The return of aquatic vegetation, a controlling component of the riverine system, constitutes a major improvement in the biotic integrity of this river reach.

Although the aquatic insects, snails, clams, mussels, and fishes still are not as diverse or numerous in the Des Plaines as in the neighboring Kankakee River, the partial recovery of this heavily impacted area is of great value because it is situated in a densely populated area in northeastern Illinois where there is a shortage of outdoor recreation. The GIS can be used in conjunction with aerial photography to document further changes in the vegetation that indicate improvement or remaining problem areas.

By *Pamela Tazik and Richard Sparks, Aquatic Biology Section*

On Lakes . . .

Over 85,000 impoundments are present in Illinois, 2,937 of which are lakes of six acres in size. Although 901



Standard Contour and 3-Dimensional Profiles of Ferne Clyffe Lake in Johnson County, Illinois.

of these impoundments are state or publicly owned, lake maps and related data were difficult to obtain, dated, or nonexistent. Recently scientists from the Aquatic Biology Section, under the direction of Peter Bayley in association with the Illinois Department of Conservation, have begun to address this need. As part of the Fisheries Analysis System that stores statewide fisheries data on microcomputers and in the Illinois GIS, morphometric data are being collected and, with the aid of ARC/INFO, maps are being generated for lakes managed by the Department of Conservation.

ARC/INFO requires that lake morphometric data be entered as a series of points of known location and depth. This information is generally gathered by taking series of continuous depth soundings across the length and width of the lake. Alternatively, information from existing maps can also be used after a field check for accuracy. Depths from the sounding strip charts are analyzed, corrected to normal pool elevation, and transferred onto an outline of the lake basin as taken from field-checked aerial photographs or topographic maps. Contour lines are then drawn from transect-depth data, creating a simple map that can be digitized onto the PRIME through ARC/INF0.

The main advantage of using a GIS system such as ARC/INFO, apart from its obvious ability to produce maps of various detail and scale, is its power as an analytical tool. GIS allows for the integration of lake-specific data, such as shoreline habitat assessment, which includes water chemistry and the extent of aquatic vegetation and land cover. Geomorphological, meteorological, and anthropological data of watersheds are also easily related. The TIN (Triangulated Irregular Network) system of ARC/INFO is being used to create 3-dimensional models of lake basin shape. TIN outputs calculations of morphometric parameters such as lake volume, bottom surface area, and average slope and depth, as well as 3-dimensional graphics of basins.

The primary result of this work will be a series of maps that the Department of Conservation can modify and use for distribution to the general public. These maps will aid district fisheries managers in their assessments of fish populations and fisheries in conjunction with the database of the Fisheries Analysis System. The consolidation of data in ARC/INFO also permits the influence of lake morphometric and watershed characteristics on fish community composition and structure to be examined on a statewide level.

This research is supported by the Federal Aid in Fish Restoration Program (Project F-69-R).

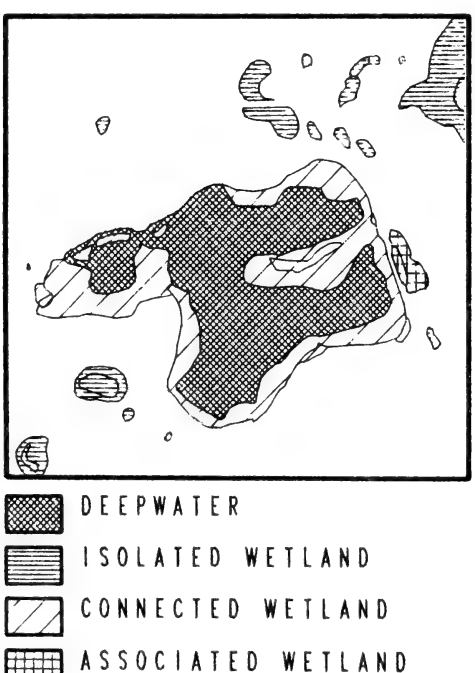
By *S. T. Sobaski, B. Newman, D. Austen, R. Maher, and P.B. Bayley, Aquatic Biology Section*

On Wetlands . . .

Wetlands are areas transitional between dry land and the aquatic environment where the land is at least periodically saturated or covered by water. Commonly, these areas are known as marshes, swamps, bogs, and so forth. Only recently have wetlands been recognized for the important variety of functions they perform, including flood storage, erosion control, pollution filtration, wildlife habitat, and recreation.

At one time, wetlands were abundant in Illinois. However, an estimated 95 percent of the wetlands found in presettlement times have been destroyed. Because of the value of this resource and its rapid decline, a management and protection program was needed.

Through the joint efforts of the Natural History Survey, the Department of Conservation, and the U. S. Fish and Wildlife Service, a wetlands inventory was developed for Illinois based on the National Wetlands Inventory, a nationwide effort by the Fish and Wildlife Service to locate and classify wetlands and deepwater habitats. At the most general level, this inventory recognizes five basic wetland and deepwater types—marine, estuarine, riverine, lacustrine, and palustrine. These are further subdivided according to factors such as soil or substrate type, plant community, water regime (e.g., temporarily flooded, permanently flooded), and man-made modifications.



Wetlands maps were created by the Fish and Wildlife Service through photo interpretation of high altitude, infrared photographs. The maps were then converted to digital form. The automation and installation of the wetlands data on the GIS have taken over two years and will be completed by the end of 1988.

Illinois wetlands data are stored as over 1,000 individual coverages based on the boundaries of 7.5 minute U. S. Geological Survey quadrangle maps. Data for each coverage exist as a set of three files—polygon, line, and point. These files contain descriptive information such as area, perimeter, length, acreage, and wetland code.

The database represents an enormous potential for environmental scientists, resource planners and managers, and engineers who need to analyze wetland resources in a particular geographic area. Numerous uses have already been found for the wetlands data, including proposed sitings of landfills, road construction, and the superconducting super collider. The high level of detail inherent in the data, however, can act as a limiting factor by sometimes making data analysis a formidable task.

Consequently, current research is pursuing ways to refine and enhance the data. As an initial step, development of an alternate classification system based on a logical grouping of the present system is aiding data analysis by reducing the number of total habitat types from several hundred to fewer than sixty. Additionally, a computer-derived system is being developed to link individual wetlands into larger groups, or wetland complexes. Individual wetlands will be categorized as isolated, connected, or associated, according to their spatial relationships with other wetland and deepwater habitats.

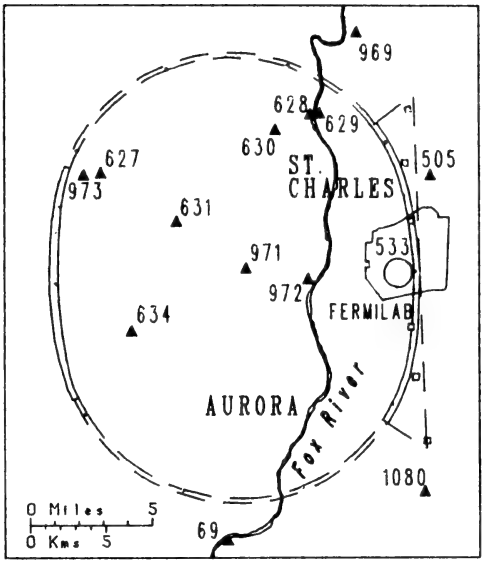
By *Liane Suloway, Faunistic Surveys and Insect Identification Section*

On Siting the SSC . . .

Illinois was prominent in the national competition for the Superconducting Super Collider (SSC), a high energy physics research facility under the auspices of the U.S. Department of Energy. The state's efforts, headed by the Illinois Department of Energy and Natural Resources, have spanned the past five years. The GIS proved invaluable and versatile throughout the site selection process in assuring Illinois' position as a top competitor for the project. The extensive database maintained by the Natural History Survey on the wildlife and plants of Illinois, including their distribution and abundance, their habitats, and their life histories and status within the state, was supplemented with computerized databases on wetlands, natural areas, soils, property boundaries, and other information necessary for siting the SSC and evaluating its potential environmental impacts. The site proposed for the SSC lies 40 miles west of Chicago near Batavia and incorporated the existing particle accelerator at Fermi National Accelerator Laboratory (Fermilab).

Initially the GIS was used by decision makers to help identify the best possible site for the 53-mile, oval-shaped tunnel and its associated surface facilities. Finding a location for the SSC that possessed minimal negative impacts and no fatal flaws was a challenging task. The GIS was instrumental in helping to meet this challenge. Subsequent to the identification of a site that met the requirements set by the U. S. Department of Energy, the GIS was used extensively in analyzing and assessing the potential environmental impacts associated with the construction and operation of the SSC. Many state agencies, including the other divisions of the Department of Energy and Natural Resources, were involved in this effort. Much of the information generated from the GIS was provided to the U.S. Department of Energy to assist in its preparation of an Environmental Impact Statement.

One important resource is the abundant and diverse wetlands scattered throughout northeastern Illinois. The computerized version of the National



Illinois natural areas and the proposed SSC site.

Wetlands Inventory, discussed elsewhere in this publication, was used extensively to assess the potential impacts of the project on wetlands. The most significant wetlands within the proposed SSC site are on land already owned by the federal government and dedicated to use as a high energy physics research laboratory. The vast majority of these wetland areas were created as a result of Fermilab. This was revealed by the GIS when wetlands created by human activity were extracted from the database and subsequently mapped.

A detailed inventory of Illinois Natural Areas was also used in the siting and evaluation process. Initially these were identified as areas to be avoided in siting. Inventories of the character of these areas and the species inhabiting them were then used to characterize unique natural resources within the site and to provide baseline data for impact assessment. The identification of federal and state threatened and endangered species within the project area was also provided by the GIS, thereby permitting an evaluation of the potential threats to the species.

Hundreds of maps of the proposed site and its resources have been produced using the GIS to assist in communicating the character and suitability of the site for the SSC. Numerous site

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visits by representatives of the Department of Energy were enhanced by the variety of data that was made available to them in map form.

The Natural History Survey was actively involved in the characterization and identification of impacts the SSC would have on the biological resources of the area and the state. The GIS evaluation provided a common geographic frame of reference and a means of accessing over 40 individual data layers. The breadth, detail, and accessibility of information contained in the GIS enabled the state to respond quickly and authoritatively to ongoing requests for information and analysis. The efforts expended on the SSC and the computerized database that resulted will be of continued use to researchers, local agencies, and the state.

By *Mark Joselyn, Faunistic Surveys and Insect Identification Section*

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Innovative Woodland Management Methods Produce Multiple Benefits

In Illinois, as in many parts of the country, most of the wooded landscape is controlled by nonindustrial private owners. Most of these private woodlands, however, are unmanaged or mismanaged. This is unfortunate because good management can greatly increase the economic and environmental values of woodlands.

Many attempts have been made by natural resource agencies to stimulate active management of private woodlands. Numerous factors are involved, but the traditional fixation of foresters on commercial timber production has been an important part of the problem. Foresters are now listening more carefully to the desires of woodland owners and are beginning to design management systems that will better meet the objectives of their clients.

Woodland owners are saying they want their woodlands to provide good wildlife habitat, natural beauty, firewood and timber for personal use, and recreational opportunities, as well as income from the sale of wood products.

Two "new" approaches to the problem of producing multiple woodland benefits on small acreages are being developed by Survey ecologist Christopher Burnett. The investigation of these methods was initiated as part of a study on Illinois' woody biomass energy resources (see *INHS Reports*, Nos. 261 and 267), but the practices have much broader application. Although the methods being researched are new to North America, they are based on ancient woodland management traditions of pre-industrial Europe where multipurpose woodland management was practiced for many centuries.

Honey locust pollards with 15-year-old sprouts being removed and weighed.

The first method under study is coppice with standards. Coppicing is the practice of periodically cutting trees off at the ground and allowing them to regenerate from stump sprouts; a coppice is simply a woodland composed of such trees. Much research has been conducted recently on coppicing dense plantations of fast-growing trees as a commercial energy source, but these techniques are designed for large-scale industrial use rather than for small landowners. Furthermore, industrial energy coppices produce few environmental benefits. They usually contain only one species and are harvested in large clearcuts on very short cycles. In contrast, traditional coppices are composed of

several species, and include a substantial proportion of standards, trees that are allowed to grow for several coppice cycles before being harvested. Thus, the coppice-with-standards method continuously maintains a diverse vegetation throughout the entire woodland. This vegetation structure not only provides a ready supply of diverse wood products, it also provides good wildlife habitat, soil protection, and visual quality.

The second method is a variant of coppicing known as pollarding. Where livestock or certain kinds of wildlife are abundant, it is difficult to regenerate trees after a harvest by seedlings or sprouts because of browsing on the tender stems. Pollarding solves this problem by cutting trees off on tall stumps so that the regenerating sprouts are above the reach of browsers. Pollarding is still widely practiced in other parts of the world today and has good potential for several applications in the Midwest. In pasture systems, pollards can provide protection for livestock without reducing forage production, and they are compatible with fire management of native prairie grass forages. In fencerows, pollards provide a windbreak without occupying too much land. Wherever they are used, pollards tend to develop cavities that are critical for many types of wildlife.

Copies of the report, *Woody Biomass Energy Resources of Illinois*, (R982) may be obtained from the Survey.

By *Christopher Burnett, Section of Wildlife Research*

Identification of Toxic Substances in the Upper Illinois River

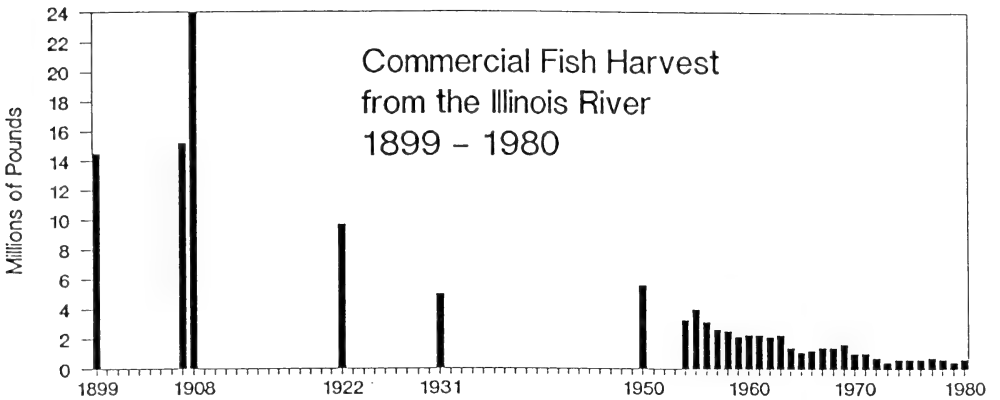
The Illinois River was once one of the most biologically productive rivers in the United States. In 1908, a 200-mile reach of the river between Hennepin and Grafton produced 10 percent of the total U.S. catch of freshwater fish. Over 2,000 commercial fishermen were employed to harvest 24 million pounds of fish (178 pounds per acre) annually. Waterfowl occurred in such abundance that they were hunted and trapped for commercial markets as well as for sport. By 1970, the annual fish harvest had dropped to just 4 pounds per acre and waterfowl populations were a minute fraction of their former levels. The situation has not improved since then.

Past studies at the Natural History Survey suggest that the decline in populations of bottom-feeding fish and diving ducks was caused by the disappearance of their food base, sediment-dwelling aquatic invertebrate species. Other Survey studies have shown that these invertebrates cannot re-establish themselves in the Upper Illinois River because of one or more toxic substances in the bottom sediments.

In early 1989, two Aquatic Biology Section scientists, working in collaboration with Southern Illinois University, will begin a study of the problem to discover what is causing the toxicity and to pinpoint its source. They will sample sediments at 1-mile intervals along the river from Joliet to Chicago. These samples will be screened for toxicity by a series of rapid, low-cost laboratory tests with microscopic bacteria, algae, and nematode worms. Samples found to be "hot" will be studied in greater detail. Using differential solvent fractionation, groups of chemical constituents extracted from the sediments will be tested individually to detect the most toxic fractions, greatly narrowing the range of possible target compounds. The most toxic chemical fractions will then be tested in a functional bioassay with one of the invertebrate food species that has disappeared from the study area—the fingernail clam, *Musculium transversum*. Researchers will return to the sites where the most toxic samples were taken and sample again at much closer intervals.

At the conclusion of the 2-year study, the investigators hope to know the source and what caused the declines in invertebrate populations. Armed with this knowledge, the State's environmental managers will be able to reduce and control the contamination, allowing invertebrate populations from unpolluted tributaries to recolonize the Upper Illinois River.

This project is funded jointly by the Environmental Protection Trust Fund



Commission, the Department's Environmental Research Program, the U.S. Fish and Wildlife Service, the Illinois Department of Conservation, and the Survey.

By *Phil Ross and Richard Sparks, Section of Aquatic Biology*

Water Stress and Its Effect on Plant Growth and Crop Yield

Since the earliest days of agriculture man has recognized the inhibitory, and sometimes devastating, effects of drought on crops. The summer of 1988 brought more awareness of the importance water plays in plant survival. When water is limiting, almost all aspects of plant development are affected, but the most visible effects of drought are a reduction in plant growth and a decrease in crop yield. Both plant growth and crop yield reflect dry matter accumulation by the plant, which depends largely on net photosynthesis; total photosynthates or sugars produced minus those that are used to maintain plant growth and vigor. Thus photosynthesis is a very critical plant function and it is affected greatly by availability of moisture. The level of water stress a plant experiences during periods of low rainfall depends on a number of factors; e. g., the rainfall pattern, the type and profile of the soil in which the plant grows, the root system of the plant (deep vs. shallow), and the environmental conditions to which the plant is exposed (wind, temperature, and relative humidity). The water-stressed condition or water potential of plants is generally expressed in bars or pascals (1 bar = 100,000 pascals) and they are always negative values since the free energy of pure water is zero.

Not all plant species respond to water stress to the same degree. For example net photosynthesis, or dry matter accumulation, of two important Illinois crops is quite different. In soybean, net photosynthesis is relatively unaffected until the water potential of the plant drops below −11 bars. Corn, however, shows a decline in photosynthesis whenever the water potential drops below −3.5 bars. At a water stress of about −15 bars net photosynthesis is inhibited by about 75 percent in corn but only by about 40 percent in soybean; photosynthesis in soybean is less sensitive to water stress than in corn. The photosynthetic response to water stress is a physiological attribute and can be altered by plant breeders through genetic manipulation. For example, of released soybean varieties between 1935 and 1975, an average water potential that plants experienced improved by 14 percent and grain yield increased by 18 percent. Once there is an understanding of the physiological mechanisms that are inhibited by water stress, further improvements will be forthcoming.

Plant water potentials of −3 bars are generally considered normal conditions, and values of −10 to −12 bars are common for plants grown out-of-doors during summer months. Some plants are quite resistant to water stress. Field-grown red beet for example does not show an inhibition in photosynthesis

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until the water potential drops below −20 bars, and some species of mimosa are even more resistant, inhibition of photosynthesis does not start till the water potential is well below −30 bars. In general terms it means that everything being equal, plants that show less inhibition in photosynthesis during dry summer conditions have a better chance of survival than plants that cannot tolerate drought.

Plant growth is a function of cell division, that is an increase in number of cells and of cell enlargement, an increase in cell size. Both cell division and enlargement result in an increase in biomass or dry matter. During drought stress when photosynthesis is inhibited, cell division is more dramatically affected than cell enlargement; and it is for this reason that formation of new twigs or branches is inhibited to a greater degree than twig or branch elongation.

The exact relationship between decreases in vegetative dry matter and grain yield is not clear. Yield is determined more by total photosynthesis taking place over the whole growing season rather than that which occurs during the seed-filling period alone. From all evidence, translocation of dry matter from the vegetative parts of the plant to the seed is less sensitive to drought than photosynthesis. From an evolutionary point, redistribution of biomass is probably a noteworthy mechanism for assuring the survival of a species under dry conditions.

It is well known that moisture stress increases membrane permeability, making the photosynthetic apparatus more fragile. The increase in membrane fragility has been explained in terms of changes in its structure and it was found that water stress significantly affects important structural lipid components of membranes. In future research, the biochemical control of membrane modification will be examined by Survey scientists.

By *Claus Grunwald, Section of Botany and Plant Pathology*

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Upland Sandpipers on Illinois Prairie-Chicken Sanctuaries

Grasslands on the prairie-chicken (*Tympanuchus cupido*) sanctuaries in Jasper and Marion counties are used by a wide array of Illinois wildlife. Upland sandpipers (*Bartramia longicauda*) constitute one of the most interesting and graceful harbingers of spring in sanctuary meadows. Like the prairie-chicken, the upland sandpiper is an endangered species in Illinois. Results of a national survey in the 1970's showed that sandpipers were not known to be increasing anywhere because of continued degradation of grassland habitat.

Survey wildlife ecologists John Buhnerkempe and Ronald Westemeier analyzed available data on upland sandpipers breeding on the sanctuaries between 1963 and 1984 for a 1988 article in the Transactions of the Illinois Academy of Science. The average arrival date in Jasper County of upland sandpipers that presumably wintered in Argentina was April 10. Nest initiation typically began about 2 weeks later. Censuses showed 7-8 breeding pairs in 1983-1984 and again in 1988 — about one pair per 40.5 ha (100 acres) of grassland.

Only 33 sandpiper nests were found while searching 2,940 ha (7,265 acres) over the 22-year study; 12 additional nests were found since the published study. Of 34 nests whose fates were known (each with 4 eggs), 21 hatched (62 percent), 11 were destroyed by mammalian predators, and 2 were abandoned.

Sandpipers made selections from an array of cover types, management practices, age classes, and cover heights available on the sanctuaries. Redtop (*Agrostis alba*)-timothy (*Phleum pratense*) meadows predominated on the sanctuaries and use by nesting sandpipers was proportionate to availability of these types; however, selection was shown for mixed grasses and forbs — those in which no plant species was clearly dominant. Fields of uniform grasses and legumes, those most suitable for grass seed harvesting, were avoided. Unfortunately, combine harvesting of redtop-timothy seed by tenants is the primary approach to maintaining nest cover for prairie-chickens. Upland sandpipers chose grassy stands that had been high mowed for weed control or burned the previous summer or fall. Sandpipers nested in all age classes of grass-forby cover, but nest

The upland sandpiper as it appears on the prairie-chicken sanctuaries in Jasper and Marion counties (photo by Bob Short).

A sandpiper nest photographed on the Marshall Field III prairie-chicken sanctuary (photo by Ronald L. Westemeier).

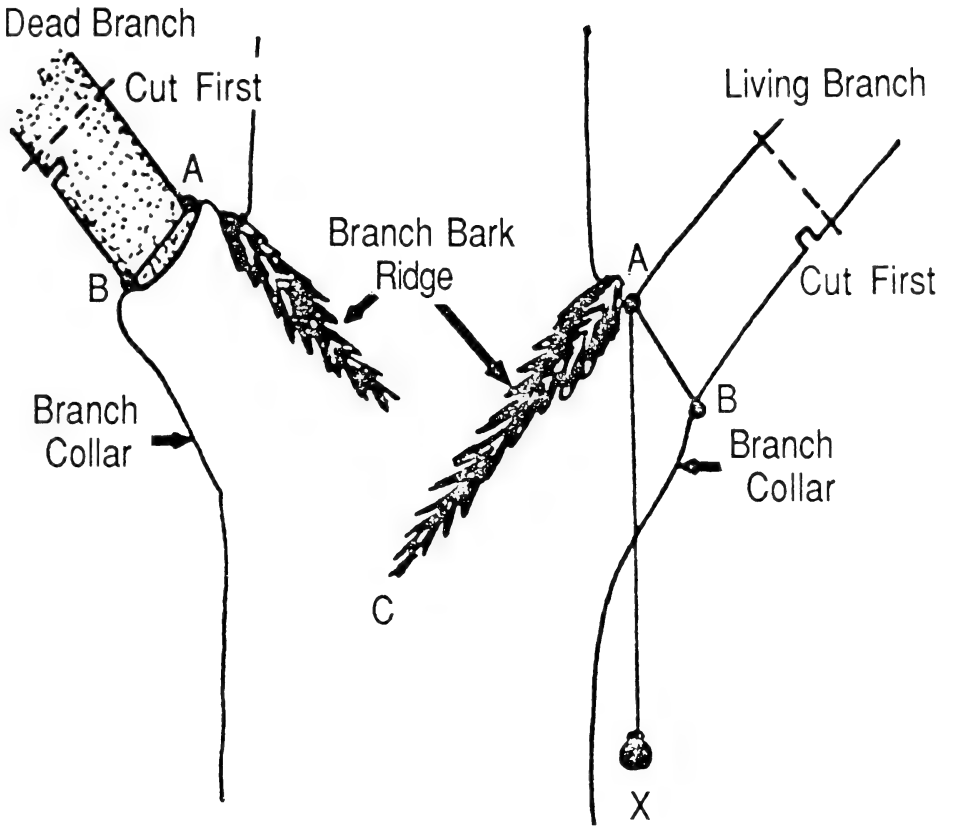
densities were highest in sods that were in at least the ninth season of growth since seeding.

Forbs occurring at least 5 percent of the time at nest sites included goldenrod (*Solidago* spp.), aster (*Aster* spp.), ragweed (*Ambrosia* spp.), and yarrow (*Achillia millefolium*). Grasses with at least a 5 percent frequency of occurrence were those of medium height and narrow leaves such as redtop, timothy, brome (*Bromus* spp.) and bluegrass (*Poa* spp.). Tall, rank prairie grasses (*Andropogon gerardi, Sorghastrum nutans,* and *Panicum virgatum*) did not occur at nest sites, although stands containing these grasses amounted to 15 percent of the area searched. Similarly, on Goose Lake Prairie, Illinois' most extensive area of native mesic tallgrass prairie, upland sandpipers limited nesting to patches of bluegrass.

Upland sandpipers on the Jasper County sanctuaries nested in vegetation 17-33 cm (6.7-13.0 inches) in height, such as old redtop-timothy meadows rotary mowed for weed control the previous summer. The single nest found in a field of prairie grass was in a field that had been burned the preceding winter and the new growth was still short when the nest was initiated. Thus, freedom of vision and movement are clearly important attributes of sandpiper nesting habitat. These attributes, plus insect abundance, are also important for breeding sandpipers. Although quality habitat for sandpipers is not prime for nesting prairie-chickens, patches suitable for sandpipers help diversify the vegetative complex on sanctuaries and may contribute importantly to brooding areas for prairie-chickens.

Management strategies designed to benefit upland sandpipers include the use of cool-season introduced grasses that are allowed to reach 10-12 years of age before reseeding, in order to diversify. Management of such fields may include a 3-year rotation of rotary mowing to a height of 15-30 cm, no disturbance, and prescribed burning. Moderate grazing of grasses would also provide suitable nesting and brooding cover, but further research on grazing, particularly of prairie grasses, under Illinois conditions is needed. Delayed mowing (at least to after July 1) of likely sandpiper nest-brood habitat, if necessary, would help to avoid losses of eggs and young. Such measures should continue to maintain or increase sandpiper numbers on the sanctuaries. On private farmland, the current Federal programs of cropland diversion to grassland, such as the Conservation Reserve Program, may give this beautiful prairie bird a much-needed assist.

By *Ronald L. Westemeier, Section of Wildlife Research*



Pruning Cuts in Trees

The invention of the chain saw made removing branches from trees much easier. However, Dr. Alex Shigo and colleagues are now telling arborists and homeowners that they are making the pruning cut in the wrong place and describe natural target pruning (U.S. Forest Service Information Folder NE-INF-58-84). In natural target pruning the objective is to leave the branch collar on the primary stem while removing the remainder of the branch. This frequently requires the final cut to be at approximately the same angle from the vertical as that formed by the branch bark ridge. This method leaves a smaller area of exposed wood, retains the branch collar, and requires an upstroke with the chain saw when the angle between the trunk and branch is acute.

With conventional pruning, the final cut with the chain saw is a downstroke with the chain saw. It is not a flush cut. It begins outside the branch bark ridge (point A in Figure 1) and proceeds slightly outward (from point A to approximately the point of the arrow identifying the branch collar). Care is taken not to injure with the chain saw the main stem above the branch. In removing a dead branch with a callus collar, much of the callus tissue would be removed to avoid leaving a projection (stub) on the trunk. The conventional cut creates a larger wound than the 'Shigo' cut. Closure of the wound depends on the rate of development of callus tissue around the wound margin. One 4-year study in the Illinois Natural History Survey arboretum had as its objective the comparison of wound-closure time following natural target and conventional pruning of living branches from three species of trees.

The trees used in the study were pin oak, Norway maple and sycamore, and were planted 12 feet apart in 100-tree blocks. The trees had trunk diameters of 4 to 7 inches when the test began in 1983. The branches removed had diameters of 1 to 1.5 inches. Ten different

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trees each year for 4 consecutive years of each species were selected for pruning. Four living branches from each tree were removed: two by the 'Shigo' method and two by the conventional method in the early spring. The diameter of the branch removed and the width of the original wound were measured in the spring. The width of the wood remaining exposed was measured annually in the fall.

Depending on species, 'Shigo'-cut wounds were 3 to 6 percent wider than the diameter of the branch; conventional-cut wounds were 32 to 50 percent wider. Wound callus around conventional cuts grew much faster than callus around 'Shigo' cuts (0.6 versus 0.3 inch the first year and 0.8 versus 0.5 inch the second year). After one growing season the amount of wood exposed on conventional and 'Shigo' branch wounds was approximately equal, even though the conventional cuts were originally much larger. After the second growing season, more conventional than 'Shigo' cuts were fully closed.

The conventional and 'Shigo' cuts each have advantages and disadvantages. The conventional cut makes a larger wound and subjects the interior wood in the tree to the greater likelihood of discoloration and decay. Discoloration is assured, and decay may or may not occur. The conventional cut closes rapidly because of the proximity to photosynthate and growth regulators in the phloem, thus enhancing tissue regeneration. The conventional cut is aesthetically pleasing in that it does not leave a semblance of a stub. The conventional cut is easier and safer to make because of the downward stroke with the chain saw.

The 'Shigo' cut makes a substantially smaller wound and is through only the branch tissue. There is little or no likelihood of discoloration or decay occurrence in the main stem. The 'Shigo' cut, however, is more dangerous to make with a chain saw in that an upstroke is frequently required in order to "hit the targets" correctly. The callus collar remaining on the main stem is also not aesthetically pleasing to some tree owners.

Since there are advantages and disadvantages to each method of pruning, the question that remains to be answered by arborists and homeowners is, which is the more serious: (1) the discoloration, possible decay and internal defects that may occur following use of the conventional pruning method, or (2) the aesthetic displeasure of humans and the slow closure of wounds on trees resulting from the natural pruning method?

By *Dan Neely, Section of Botany and Plant Pathology*

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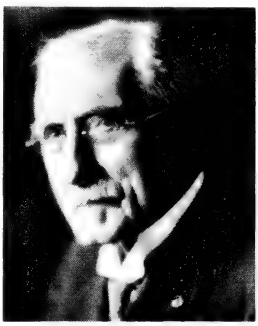
MARCH 1989, NO. 285

Stephen A. Forbes Biological Station



DR. STEPHEN A. FORBES

The oldest of the Survey's field stations, the Forbes Biological Station at Havana, has operated on the Illinois River since before the turn of the century. On May 5 ceremonies will be held to commemorate the 95th anniversary of the establishment of the station, the 50th anniversary of the first permanent building, the dedication of a new addition, and the official naming of the station after its founder, Dr. Stephen A. Forbes.

Forbes, foremost American naturalist and renowned biologist, was the first Chief of the Survey and has been called the "father of the Survey." As early as 1876 Forbes had begun studying the distributional records and food habits of fishes in the Illinois River and elsewhere in Illinois. His broad interest in aquatic biology included crustaceans, leeches, protozoans, rotifers, aquatic insects, and fishes. In 1887, he wrote *The Lake as a Microcosm,* a seminal work on the biological phenomena associated with fluctuating water levels that was to provide an important conceptual framework for his own research and that of a generation of scientists to follow.

Forbes' devotion to the Illinois River made him an ardent spokesman for a biological station on its shores. In response to his efforts, the trustees of the University of Illinois authorized field operations at Havana at their March meeting in 1894 and appropriated $1,800. On the first of April, Forbes opened the station for the "continuous investigation of the aquatic life of the Illinois River and its dependent waters."

Fieldwork on the Illinois River was conducted from a chartered cabin boat on Quiver Lake. It was equipped with nets, plankton apparatus, and other collecting equipment. There was a kitchen and sleeping accommodations for four. Thus the Havana Station became the first inland aquatic biological station in America equipped for continuous investigation and the first in the world to undertake the serious study of the biology of a river system. In 1895 a 60-foot houseboat was built in Havana from plans drawn under Forbes' direction. This floating biological laboratory was brought to the station in September of 1896. With no power of its own, it was towed by a 25-foot steamer, the *Illini.* This houseboat proved to be a comfortable and efficient laboratory for as many as 15 workers and had the very great advantage of mobility.

The foresight of Stephen A. Forbes in establishing a biological station on the Illinois River has made possible many significant contributions to an understanding of the river ecosystem. Forbes' goals for the station included "a comparison of present conditions with those of the former time." He intended "to study the river as a unit with special reference to its economic and hygenic protection and improvement; to work out the details of its biological regimen, by a separate study of special problems; and to carry on comparative studies between the Illinois, the Mississippi, and the Missouri, all readily accessible from the station." These goals remain valid today.

Charles A. Kofoid joined the staff in 1895 and his major area of investigation was the plankton of the Illinois River. When Forbes looked back on the research conducted at the station from its genesis to 1903, he noted that over 6,000 collections had been made — about 500 were fishes, some 2,000 were plankton collections, and a variety of aquatic forms accounted for another 3,500.

In 1903, Robert E. Richardson arrived at the station. Richardson documented the effects of pollution on the bottom fauna and fish yields of the river. In 1908, Forbes and Richardson published their classic book *The Fishes of Illinois,* which was to remain a unique publication for more than 40 years.

In July of 1948, William C. Starrett was hired by the Survey to continue aquatic studies on the rivers. In 1949, Starrett was placed in charge of the Havana Station and began a study of Lake Chautauqua, a shallow floodplain lake of about 3,500 acres.

In April of 1953, William Starrett and 12 other charter members founded the Midwest Benthological Society at the Havana Station. Since then the society has achieved national status as the North American Benthological Society with a membership of more than 1,200.

Wildlife research at the Survey began in the 1870s when Forbes investigated the food habits of birds. But it was not until the 1930s that wildlife research was fully recognized in the Survey's program.

In recognition of the importance of waterfowl to Illinois the Survey employed Arthur S. Hawkins and Frank C. Bellrose to initiate a waterfowl research program in 1938. For two years Hawkins and Bellrose traveled the Illinois Valley, observing waterfowl and examining habitat. Wood duck studies were also begun in 1938 with the collection of preliminary information on nesting biology.

During the depression years of the late 1930s, the federal government established work programs that made possible a variety of construction projects. The Survey made use of that opportunity to construct a building to house the Havana Station. In May of 1939, the Bureau of Biological Survey of the U.S. Department of Agriculture granted the Survey a special use permit on the Chautauqua Migratory Waterfowl Refuge. This 99-year permit was the first to grant a nonfederal agency occupancy on a federal refuge. The frame structure of the first permanent building for the Havana Station was completed in early 1940, a mile or so from the site on Quiver Lake where Forbes had established the Biological Station in 1894.

In January of 1940, Hawkins, Bellrose, and John M. "Frosty" Anderson moved into the newly completed building to begin what would become one of the most productive waterfowl research programs ever conducted at a field station. The next year Jessop B. Low joined the wildlife staff, and studies of ducks in the Illinois Valley proliferated.

In 1948, Bellrose initiated the aerial censuses of fall waterfowl migration that were begun in the Illinois River and the Mississippi River floodplain. Winter and spring censuses of those areas were added in 1955. Robert D. "Tud" Crompton, who began working at the station in 1948, assumed responsibility for the aerial censuses in 1970 in addition to his work on the wood duck project.

Bellrose served as director of the Havana Station from 1972 to 1982. He published landmark works such as *Lead Poisoning as a Mortality Factor in Waterfowl Populations* and *Ducks, Geese, and Swans of North America.* The latter has sold over 250,000 copies and was declared best book publication of 1977 by The Wildlife Society. Bellrose received The Wildlife Society's highest honor, the Aldo Leopold Medal, in 1987 and Governor James Thompson declared February 1, 1988 as "Frank Bellrose Day in Illinois." He continues to work on a book devoted to the wood duck, *The Unique Wood Duck: Its Biology, Ecology and Management,* which is scheduled for completion in 1989.

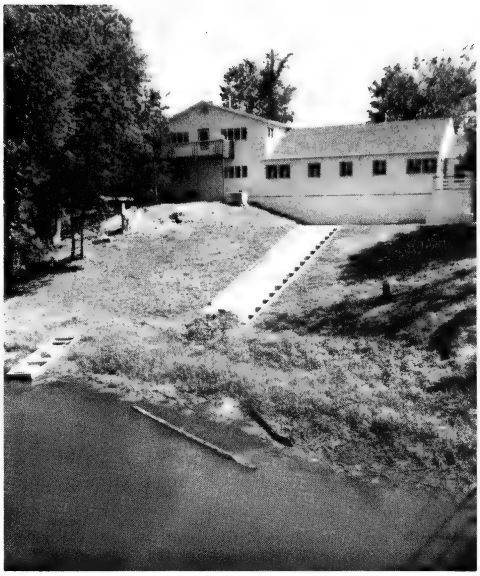
In July of 1972, Richard E. "Rip" Sparks joined the Survey and was stationed at Havana. His studies have included the toxicity of contaminants to bivalves and fishes in the Mississippi and Illinois rivers, the effects of commercial

navigation on aquatic flora and fauna, and more recently a series of studies concerning the status, disease, harvest, and management of mussels in the Illinois and Mississippi rivers. Current studies investigate interactions between mussels and sport fishes and monitoring movement patterns and habitat utilization of radio-tagged channel catfish in the Illinois River near Havana.

In 1981, the Havana Station and its study areas were designated an Experimental Ecological Reserve by the Institute of Ecology and the National Science Foundation. From 1982 to 1989, the station was one of 18 sites representing major ecosystems of the United States funded by the National Science Foundation under the program for Long-term Ecological Research (LTER). Sparks was the principal investigator of the LTER project for the interinstitutional study of the biological structure and function of the Illinois and Mississippi rivers.

Stephen P. Havera joined the wildlife staff of the Survey in 1972 and transferred to the Havana Station in 1978 to participate in a major study regarding the diversion of water from Lake Michigan into the Illinois Waterway. Since 1980, Havera has supervised a waterfowl project that will culminate in a forthcoming book, *Waterfowl of Illinois: Status and Management.* In 1982 Havera became director of the Havana Station. Studies conducted by Havera and assistants in 1985 investigated the distribution and secondary lead poisoning of bald eagles in Illinois and resulted in the publication, *Distribution and Abundance of Winter Populations of Bald Eagles in Illinois.*

In 1986, the National Science Foundation awarded $50,000 to the station toward the construction of an addition, a grant made as part of a 5-year program to offer facility and equipment support to field stations with productive scientific histories. When matching funds were obtained from the Illinois Capital Development Board, the addition was underway. In September 1988, the addition became fully operational. This addition adds 1,956 square feet for seven offices/work rooms, a library, a computer room, a lunch room, and a secretarial/reception area. The original building was renovated and contains six offices/work rooms, a conference room, and a basement workshop/storage area.



The new addition to the Forbes Biological Station as completed this year (photo by Michael Jeffords).

In June of 1987, the sister surveys — the Water Survey, the Geological Survey, and the Natural History Survey — jointly purchased two houseboats with Build Illinois funds. Christened the *William C. Starrett* and the *Robert E. Richardson,* the two vessels are equipped with a variety of monitoring devices.

Two research units have been defined to encompass current activities at the station — the River Research Laboratory and the Waterfowl Research Laboratory. During the past decade, these two research units have on occasion joined forces in interdisciplinary undertakings.

The staff at the Forbes Biological Station plan to expand work in three areas of demonstrated competence: river ecology, population studies of aquatic organisms and migratory birds, and toxicological studies to determine why certain populations have declined. In addition, they hope to make significant contributions in two areas that are currently receiving national and international attention: the function and value of wetlands and regional or "landscape" ecology.

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The River Research Laboratory has set two long-range goals. The first is to seek explanatory principles through the comparative study of large floodplain rivers and by comparing rivers with other types of ecosystems. The second is to apply those principles and the techniques of aquatic toxicology to the restoration of degraded rivers and the conservation and management of less disturbed rivers.

Because of declining continental populations of waterfowl, the long-range goals of the Waterfowl Research Laboratory will focus on migration habitat and winter habitat. Research will address such topics as the nutritional and habitat requirements of various species; the distribution, quality, and quantity of waterfowl habitat; the effects of disturbance on migrant waterfowl; and the nocturnal behavior of migrant waterfowl. Monitoring via aerial censuses will continue, but new technologies such as the computerized modeling of waterfowl numbers and distribution will be incorporated. The Illinois Geographic Information System (GIS), a computerized database that contains billions of pieces of information about the natural resources of the State, will greatly enhance research already underway at the station. Information from the wetlands inventory that was recently completed by the Illinois Department of Conservation and the U.S. Fish and Wildlife Service with help from the Survey has been entered on the Geographic Information System. Because that inventory is part of the National Wetlands Inventory, researchers at Havana will be able to conduct waterfowl research from a regional and national perspective.

The current staff of the Forbes Biological Station is dedicated to the investigation of the properties and functions of the Illinois and Mississippi rivers and the plants and animals associated with and dependent upon these wetlands. Their mission is to document the changes in those rivers, the reasons for those changes, and the results of those changes. Their most challenging aspiration is to restore a part of the Illinois Valley to some semblance of its pristine condition as one of the most remarkable, beautiful, and productive river systems in North America, to give back to the river at least part of the floodplain that was taken from it so that future generations can witness and appreciate what Forbes saw in 1894 when his studies at the station began.

By Stephen P. Havera and Katie Roat,
Forbes Biological Station

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Illinois
NATURAL HISTORY
SURVEY REPORTS

Springtime Is Here, and So Are The Snakes

As the weather changes from winter into spring, many forms of wildlife begin to emerge from their winter hibernation. Among these animals are the snakes, whose emergence delights some and frightens many. During the spring, herpetologists receive numerous calls from persons concerned about the sudden appearance of, to the callers, great numbers of snakes.

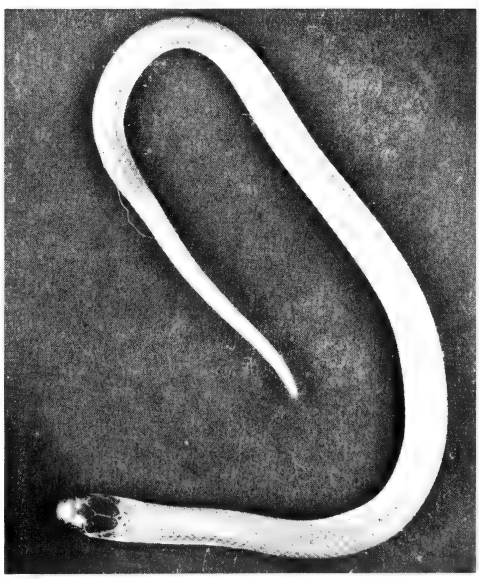
Most of the calls from persons in the northern half of Illinois are made because someone's backyard suddenly seems to have become a snake heaven. Usually the snake involved is the plains garter snake, *Thamnophis radix,* a harmless species that feeds primarily on earthworms. Plains garter snakes can be quite abundant (dozens can be encountered in a few hours), especially in vacant lots and railroad rights-of-way in cities and towns. After a flurry of activity in the spring, this species seems to disappear and is not often encountered the rest of the year.

In southern Illlinois, the species most often found in backyards (or even in houses) are the prairie kingsnake, *Lampropeltis calligaster,* or the rat snake, *Elaphe obsoleta.* Both species feed on rodents, and are attracted to areas near human habitation by the presence of their prey. Unlike plains garter snakes, these species, especially the rat snake, also appear in "numbers" (usually two or three snakes) in the fall, when they follow rodents, seeking warmth from cool nights, into houses and trailers.

There are no known repellents for snakes. If their presence is intolerable, then the best recourse is to clean up any trash in the vicinity of where the snakes have been seen (trash provides the snakes valuable shelter). However, tolerance of the snakes is preferable to any eradication scheme.

There are approximately 2,700 species of snakes in the world, and 120 species in the United States. Thirty-seven species occur in Illinois. The species occurring in Illinois range in size from the 8-inch flathead snake, *Tantilla gracilis,* to the 7- or 8-foot bullsnake, *Pituophis melanoleucus.*

Illinois snakes mate in the spring or fall, depending on the species. Approximately half of the Illinois species give birth to live young, generally from late July to September. The other half lay eggs in moist, warm areas, such as the interior of rotting logs. The flexible-shelled eggs usually hatch in August or September. Except for the mud snake,



A subadult flathead snake, *Tantilla gracilis* from Union County, the smallest species (8-inch) of snake in Illinois. The color above is tan or light gray with a black cap on the head; below, salmon pink.

Farancia abacura, a species found in extreme southern Illinois, the mother snake abandons her eggs as soon as she lays them. The mud snake reportedly stays with her eggs until they hatch.

All snakes are strictly carnivorous (when plant material is accidentally eaten, it passes unchanged through the snake's digestive tract). Some species are general carnivores, eating many kinds of animals. For instance, the racer, *Coluber constrictor,* a large species found nearly Statewide, feeds on insects, amphibians, reptiles (including other snakes), birds and their eggs, and rodents. Others are dietary specialists. Examples are the rough and smooth green snakes, *Opheodrys aestivus* and *O. vernalis,* which feed on insects and spiders. All species play an important role in the food chain, serving as controls on populations of other animals, and in turn becoming prey for other animals. Some species are economically beneficial because they eat rodents or insects; included in this group are the venomous snakes.

There are four species of dangerously venomous snakes in Illinois. They are the cottonmouth (water moccasin), *Agkistrodon piscivorus,* the copperhead, *A. contortrix,* the massasauga rattlesnake, *Sistrurus catenatus,* and the timber rattlesnake, *Crotalus horridus.*

The cottonmouth is found only in extreme southern Illinois (reports from other sites in Illinois are based on the harmless water snakes). The copperhead occurs in the southern half of Illinois. The small massasauga used to occur nearly Statewide, but it is now confined to relict populations. The timber rattlesnake, the largest and potentially most dangerous species in the State, occurs primarily in the southern half of the State, but also extends up the Illinois River to LaSalle County, and along the Mississippi River to Wisconsin. All of the Illinois species of venomous snakes can cause death; however, bites from them are rare, and there have been no recent deaths from their bites. A hiker in southern Illinois is in far more danger from a twisted ankle, wasps, feral dogs, or another human than from poisonous snakes. The copperhead is the least dangerous, and most common, venomous snake in Illinois. The timber rattlesnake is the most dangerous, from the standpoint of its size and strength of venom, yet it is a shy, retiring snake. The massasauga and cottonmouth fall between those species. All of the venomous snakes, in fact all of the snakes in Illinois, play important ecological roles and pose little danger if left alone.

An adult bullsnake, *Pituophis melanoleucus* from Mason County, one of the largest of Illinois snakes, about 8-feet long. The ground color is bright yellow or tan. The blotches are black anteriorly and posteriorly, but rich brown at midbody.

The best reference on Illinois snakes is *The Amphibians and Reptiles of Illinois* by the late Philip W. Smith. This monograph, produced as Illinois Natural History Survey Bulletin 28(1), has excellent photographs, keys, and descriptions of all amphibians and reptiles known to occur in the State at the time of its publication in 1961. It is somewhat outdated because of changes in herpetological systematics and distributional information, but it still remains the definitive work on Illinois amphibians and reptiles. A supplementary publication, *An Annotated Bibliography of the Illinois Herpetological Literature 1960–1980, and An Updated Checklist of Species of the State,* by M. A. Morris, R. S. Funk, and P. W. Smith, appeared in 1983 as INHS Bulletin 33(2). This publication summarizes sources of information on amphibians

and reptiles in Illinois that appeared between 1960 and 1980, and provides a synopsis of name changes from Smith's work. Both Bulletins are available from the Illinois Natural History Survey.

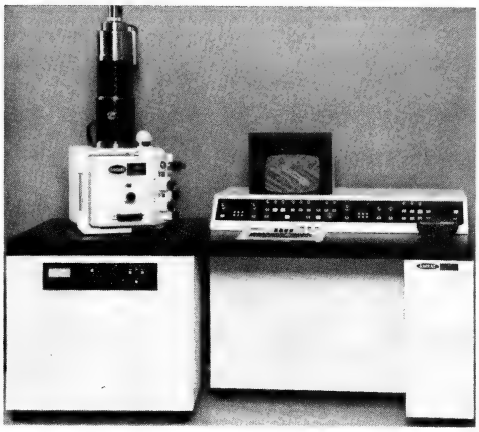
By *Michael A. Morris, Section of Aquatic Biology*

Update on the Deer Tick

Readers of *Illinois Natural History Survey Reports* will be aware that the deer tick *Ixodes dammini* was detected for the first time in Illinois in Jo Daviess County in November 1987. In the spring of 1988, a team of researchers from the Illinois Natural History Survey and the College of Veterinary Medicine of the University of Illinois began to search in other areas of northwestern Illinois for the deer tick and found it along the Rock River in Ogle County. In November and December 1988, the research team, interested volunteers, and Illinois Department of Conservation personnel examined deer at check stations in more than 50 counties throughout the State. Deer ticks were taken from deer inspected in Carroll, Jo Daviess, Ogle, Lee, Rock Island, Mercer, Knox, Putnam, Kankakee, Piatt, and Edgar counties.

That the deer tick is the vector of the causative agent of Lyme disease has been well publicized in the popular press. Over two dozen cases of the disease in Illinois have been reported since 1980. While most of these cases are believed to have been contracted in other states, some cases are thought to be of Illinois origin. Such local cases have been reported to the Illinois Department of Public Health from eight counties in the northern one-half of the state.

Persons engaged in outdoor work and recreation in Illinois are reminded that the peak period of transmission of Lyme disease is from May to July and that they should take suitable precautions against tick bite. In a tick infested area, the best protection is to wear sturdy shoes, long pants with cuffs tucked into socks, and long-sleeved shirts with cuffs. Further protection can be provided by using tick-repelling sprays applied to the clothing, not the skin.



AMRAY 1830

Those who might wish to submit ticks for identification should send them in alcohol to John K. Bouseman, Section of Economic Entomology, Illinois Natural History Survey, 607 East Peabody, Champaign, Illinois 61820.

By *John K. Bouseman, Section of Economic Entomology; and Dr. Uriel D. Kitron, College of Veterinary Medicine.* Dr. Kitron is also an affiliate of the Survey's Section of Economic Entomology.

Scanning Electron Microscope

The scanning electron microscope (SEM) is one of the most versatile instruments available for the examination and analysis of microstructures of biological samples. Four features make the SEM useful to biologists — the obtainable high resolution currently in the range of 50Å in most commercial instruments, the three-dimensional appearance of the specimen image, the wide magnification range usually in the range of X10 to X100,000, and the depth of focus.

The AMRAY 1830 is a state-of-the-art SEM with a computer-controlled vacuum system and electronics console. This instrument is operator friendly and has many automatic features such as the autovideo for even-image brightness useful in viewing and photography, the autobeam saturation and biasing, the autofocus and autostigmation of image, and the automatic labeling of image plus particle measurement. Computer-image storage and image enhancement are also

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standard features on this instrument. The AMRAY 1830 is also capable of high- and low-voltage imaging. High voltage is used for maximum resolution; low voltage is used to examine the surface of a sample rather than penetrate the specimen; better surface detail is also available at low voltage. For example, the cytoskeletal structure of any cell of the fimbrae and pili of bacteria can be easily imaged. These structures are not suitable for high voltage because the electrons pass through them as light does through a windowpane. The problems usually associated with low signal at low voltage are compensated for on the AMRAY 1830 by the computer "buffering" system in which the signal is stored and added and the noise is eliminated.

Three accessories were purchased with the instrument — x-ray microanalysis, which determines the elemental composition of the sample with a program for mapping the elements, semi-to-quantitative analysis, and image processing. The latter feature allows for color coding of topographic and elemental distribution data. Additional programs include the ability to map the location of elements in the sample.

The second accessory is a cathodoluminescence detector. When certain materials are bombarded by energetic electrons, long wavelength photons are emitted in the ultraviolet and visible region of the spectrum. Cathodoluminescence allows for "finger printing" for chemical composition of compounds such as pesticides, herbicides, and dye labels such as haemotoxylin. This is accomplished by matching the compound with its specific accelerating voltage that causes it to cathodoluminesce.

The third accessory is the backscatter electron detector. In this mode electrons are reflected with an intensity based on atomic number. In biological analysis this technique can provide atomic number contrast, i.e., to localize structures stained with heavy-metal dyes. The AMRAY 1830 has the ability to mix backscattered reflected electrons and secondarily reflected electrons in varying amounts to suit the investigator.

By *J. Leland Crane and Jean D. Schoknecht, Section of Botany and Plant Pathology*

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NATURAL HISTORY SURVEY REPORTS

MAY 1989, NO. 287

The Illinois Fisheries Genetics Program

Fisheries resource managers now realize the importance of including genetic conservation principles in their management equations. An understanding of the population genetic dynamics of the resource is vital to a comprehensive and integrative management strategy. The State of Illinois Fisheries Genetics Program is one of relatively few comprehensive and coordinated state-run fisheries genetics projects in the United States. Several Pacific northwestern states have large, on-line projects concerned with salmonid genetic monitoring. The Illinois program is unique, however, because the scope is wider (greater numbers of species of interest) and is necessarily inland.

By combining information garnered from biochemical and molecular genetic studies, breeding studies, behavioral studies, metabolic and physiological studies, and gross morphology studies with the more traditional population dynamic and conservation management approaches, the program's goal is to establish the importance of conservation genetics in fisheries as well as other biological resource management. Financial support is provided by Dingell-Johnson (Federal Aid in Fish Restoration Act) funds administered by the Illinois Department of Conservation. A close association has been developed among the Illinois Department of Conservation (IDOC) Fish Hatchery Division, Lake Management Division, and the Fisheries Genetics Laboratory of the Survey. Each is an integral part of the success of the program.

Conservation genetic principles are formulated on the premise that it is prudent to protect rare, unique, and natural gene combinations. Gene pools are the sum total of genetic variability present within and among populations, species, or communities. Gene pools constitute a resource that needs protection from eradication or mismanagement. In addition to the gene pool itself, we need to prevent irreversible interference with the dynamic processes responsible for

Research is conducted in one of several ponds of the Survey complex in Champaign (Photo by John Epifanio).

tailoring organisms to their specific environments. These processes include natural selection, speciation, natural mutation, migration, and even extinction. We are just now beginning to understand the possible long-term effects of precluding genetic considerations from management strategies. Conservation genetics recognize that single species are composed of more than a single population or *stock*. Stocks are defined as groups of individuals within a species that can mate randomly within the group and are geographically, ecologically, or behaviorally limited from mating with individuals in other such groups. Given time, natural processes lead to a divergence of gene pools. The combined effects of environmental characteristics and genetics can be expressed as heritable physical differences. Such physical differences can be used as diagnostic stock markers. Often, genetic divergence has not manifested itself physically. Subtle genetic differences can be detected only with a host of biochemical and molecular genetic techniques.

The Fisheries Genetics Laboratory of the Survey provides the technical support for the program. The laboratory has a varied arsenal of techniques available, ranging from simple enzyme analyses to more advanced DNA analyses. Continuous upgrade of techniques and state-of-the-art equipment, thanks in part to Build Illinois Equipment grants, makes possible rapid and cost-efficient results. In addition, a complex of rearing ponds are available to produce and grow experimental fishes under controlled conditions.

The program includes several specific projects that vary in scope. These range from constructing a statewide data bank of genetic resources to conducting basic research to implementing this information.

The first is a genetic catalogue of Illinois fishes. The purpose of this project is to construct a running data base of the gene pools of economically important fishes. All fish produced or attained by the IDOC fish hatcheries are sampled for their genetic make-up. Additionally, a monitoring program of many of Illinois' lakes and streams fish population provides information regarding both donor and recipient populations. Follow-up assessments provide a means by which changes in gene pools can be monitored.

Another project in the program tracks the performance of largemouth bass in the State. Illinois covers a wide range of environmental types. This may mean that largemouth stock from one environment may not perform optimally (in terms of growth, survival, and reproduction) in new or altered environments. Special genetically tagged populations of largemouth from either northern or southern Illinois sources are placed in equal numbers in test ponds around the State. By monitoring relative population sizes, growth, and reproduction we hope to determine the optimal stock for each region of the State. Such information should greatly enhance largemouth bass populations and improve angling opportunities around the state.

Two similar projects will identify the effects of fish stockings. One study uses largemouth bass, the other walleye. In each, three genetically tagged groups will be produced at the hatchery. One tag will be specific for fish to be stocked as fry, another for fingerlings, and a third for advanced fingerlings. These will be stocked into a variety of lakes around the State and monitored to identify which stocking size has the greatest recruitment into the fishable population. The results of these projects can benefit the enhancement efforts of many species, as well as largemouth bass and walleye.

The final project is a coordinated effort to identify which strain(s) of lake trout are successfully spawning in Lake Michigan. Physical tags have been used in the past to identify which strains are congregating on known spawning grounds. However, physical tags are not transmitted to their young as are genetic tags. By identifying genetic markers of lake trout strains we hope to resolve which strains are responsible for successful reproduction. If researchers concentrate their efforts on the most successfully reproducing strains, the

reestablishment of naturally reproducing lake trout populations will be more efficient.

Fisheries resource managers can improve fish populations by including a genetic perspective in their management strategies. This new strategy requires coordination with state hatchery personnel, lakes and streams managers, and basic researchers from diverse agencies. The increased short-term effort in coordination and planning are quickly outweighed by the benefit of long-term stability in fish populations, and as an important side benefit, better angling opportunities.

By *John Epifanio, Aquatic Biology Section*

Biological Control Agent of the Corn Rootworm

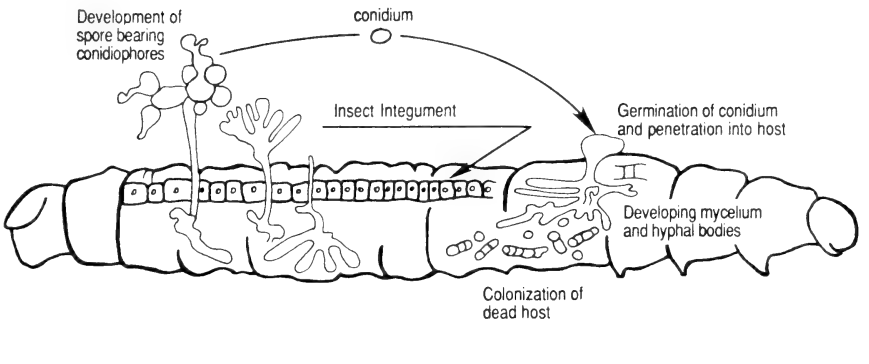
Beauveria bassiana is an entomopathogenic fungus of the Fungi Imperfecti group that infects many different insect species. It has been recognized as an insect pathogen for over 100 years and frequently causes widespread epizootics in insect populations. Many attempts have been made to use *B. bassiaana* as a biological control agent, probably because of the impressive nature of the naturally occurring epizootics. Using *B. bassiana* as a microbial insecticide has produced erratic results causing U.S. scientists to conclude that *B. bassiana,* while being an important naturally occurring biological control agent for many species of insects, it has limited value as a microbial insecticide.

Entomologists Joe Maddox and Karl Kinney began studies involving *B. bassiana* as a microbial control agent for the control of corn rootworm larvae for these reasons:

(1) *Beauveria bassiana* causes natural epizootics in rootworm populations, (2) Many strains of *B. bassiana* are available and many are pathogenic to corn rootworm larvae, (3) Because the soil provides moisture and protection from sunlight, it is an attractive medium in which to use fungal diseases as biological control agents, (4) The corn rootworm complex is a major pest of corn for which large quantities of chemical pesticides are used every year, and (5) Many chemical pesticides do not work well because of rootworm resistance and enhanced microbial degradation of pesticides.

Beauveria bassiana infections result when a *B. bassiana* conidium (asexual spore) germinates, penetrates the cuticle, and begins growing in the hemocoel of the corn rootworm. The germination of the conidium and subsequent penetration into the host cuticle are affected by microclimatic factors, temperature, *B. bassiana* strain, and the condition of the host. The penetration through the cuticle is the result of a combination of mechanical and enzymatic action. Inside the hemocoel the fungus grows, usually in the form of yeast-like hyphal bodies. These actively growing fungi produce toxins which are ultimately responsible for the death of the insect. The parasitic phase of *B. bassiana* development ends and colonization begins when the host

The Life Cycle of *Beauveria bassiana*



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dies after 4–10 days, depending on the size of the host, the strain of *B. bassiana,* the quantity of the inocullum, and the temperature. The host body is completely invaded by fungi at this time and when the atmosphere becomes saturated, the fungus grows outside the body producing more conidia.

Objectives of the Maddox–Kinney studies were to determine the effectiveness of several *B. bassiana* strains in controlling larval corn rootworms under field conditions and to investigate in the laboratory the influence of several different variables on the infectivity of *B. bassiana* to larval corn rootworms. Over a period of 4 years, several strains of *B. bassiana* were applied to the soil before corn was planted. Subsurface cultivator sweeps and anhydrous knives were modified to apply conidia in water suspensions. Conidia were also disked into the soil after being applied to the soil surface. The abundance and distribution of conidia in the soil were monitored by serially diluting soil samples and plating these dilutions on a selective medium designed to inhibit the growth of other microorganisms. Root damage ratings and corn yield were also determined for all treatments. Laboratory bioassays were conducted to investigate the variables of soil type, soil moisture, *B bassiana* strain, and antagonism by other soil-inhibiting microorganisms.

In 1986 and 1987 field trials, *B. bassiana* treatments did not significantly increase corn yield, but in 1988 corn yield was significantly higher in one of the *B. bassiana*-treated field trials.

Laboratory and field experiments suggest some reasons for this lack of control. Most of the conidia (66%) were in the top 2 inches of soil; not an ideal distribution because much larval feeding occurs below this depth. The number of *B. bassiana* conidia recovered from the soil immediately after application was less than the anticipated number and the overall distribution of conidia in the field was inconsistent regardless of the method of application. There were also strain and field differences in the loss of conidial activity from time of application until 30 days after application, suggesting that some strains are able to persist in soils and/or that some soils are more antagonistic toward *B. bassiana* conidia than others. Laboratory studies substantiated that soil moisture, the presence of other soil microorganisms, soil type, and the strain of *B bassiana* greatly affected laboratory bioassays of *B. bassiana.*

By *Joseph Maddox and Karl Kinney, Section of Economic Entomology*

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NATURAL HISTORY SURVEY REPORTS

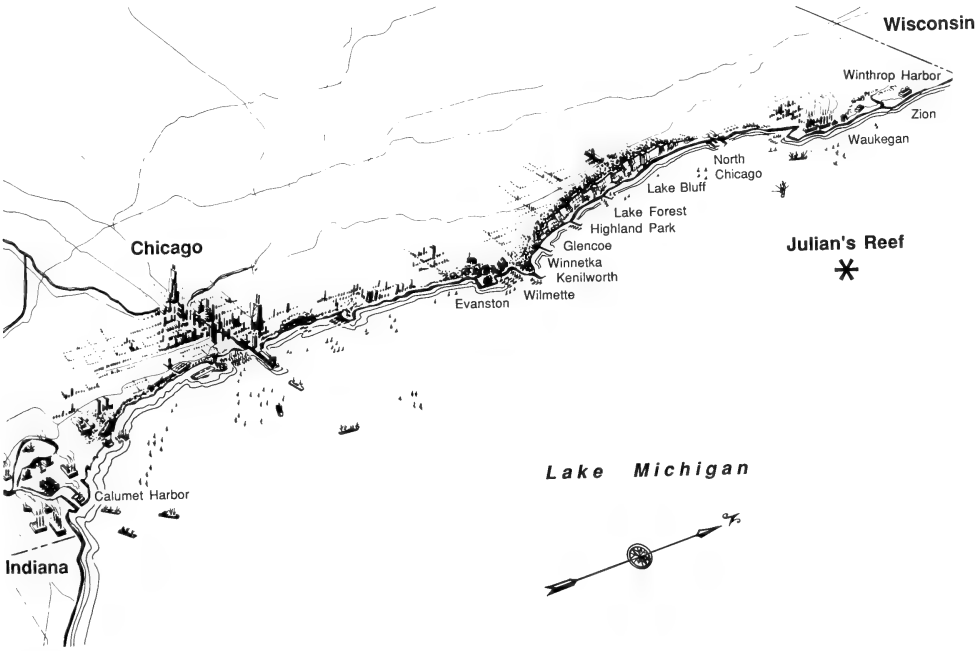
JUNE 1989, NO. 288

Lake Trout Spawning Studies on Julian's Reef, Lake Michigan

In Illinois, efforts to reestablish self-sustaining lake trout populations in Lake Michigan have focussed on Julian's Reef with well over one million lake trout stocked there. The fish have survived and grown well enough to support a lake trout sport fishery in Illinois. To date, however, no direct evidence exists to prove that the stocked fish successfully reproduce on Julian's Reef, or anywhere else in Illinois waters; although each fall over Julian's Reef the Illinois Department of Conservation is able to collect mature adult lake trout bearing viable eggs and sperm.

Until the mid-1940's native lake trout were sufficiently abundant in Lake Michigan to support commercial fishermen operating out of Waukegan and Chicago. In the early days they were caught on set lines carrying 100 to 500 hooks each. One old fisherman interviewed in the 1970's remembered taking 300 to 700 pounds of lake trout per lift. Later, gill netting became the preferred method of capture and annual commercial harvests from Illinois' waters grew to exceed 1,000,000 pounds in the early 1940's. During the years when native lake trout were abundant in Lake Michigan, Julian's Reef was probably one site used for spawning.

Sea Lampreys were first reported in Lake Michigan in 1936 The sea lamprey's primary victim was the lake trout, and by 1950 the lake trout catch had dropped to zero. Lake Michigan was not unique; lake trout were extinct in all of the Great Lakes except Lake Superior where remnant native populations persisted.



Illinois shoreline on Lake Michigan showing location of Julian's Reef.

Over 100 million lake trout, representing several different strains have been stocked in the Great Lakes since 1958 in an international effort to reestablish self-sustaining populations. Over one million fish were stocked over Julian's Reef; and this program has produced large populations of adult fish. Although some natural reproduction has been noted in each of the Great Lakes, except Lake Erie, the evidence for natural reproduction outside of Lake Superior is scant and virtually all adult lake trout now in the four lower lakes were produced in hatcheries.

Hypotheses to explain the reproductive failure are plentiful, but data with which to evaluate the hypotheses are scarce. 1. The problem may be contaminants. It is known that eggs taken from adult lake trout in the Great Lakes carry high concentrations of PCB's. But despite that the eggs are often viable; several hundred healthy juvenile lake trout produced by stirring together eggs and sperm from adults collected over Julian's Reef now reside in the Jake Wolf Hatchery. 2. There may be a behavioral problem; the stocked fish may fail to deposit their eggs over substrate that provides cracks and holes in which the eggs can be protected from predators during the months of incubation. 3. It has been suggested that stocked lake trout fail to reproduce because they lack the appropriate genetic adaptations to Lake Michigan. Native lake trout from various areas of the lake appear different from one another, and the differences may reflect adaptations to local conditions. Fishermen from several parts of Lake Michigan identified particular populations as Mackinaw trout, Beaver Island trout, redfin or reef trout, yellowfin, moss trout, deepwater trout, bay trout, etc.

During spawning seasons in each of the past four years, the Illinois Natural History Survey, with support from the Illinois Department of Conservation, has attempted to recover spawned eggs from Julian's Reef. The recovery of spawned eggs was viewed as a necessary first step toward either confirming that natural reproduction is occurring on Julian's Reef or understanding why reproduction fails there. Julian's Reef rises to approximately 100 feet below the surface at a point approximately 14 miles due east of Fort Sheridan. The distance from shore and the depth precluded extensive exploration by divers, so passive egg-collection devices were developed. Each year egg nets were deployed from a commercial fishing boat in October, prior to spawning, and recovered in late November or early December. Although the egg nets were successful in collecting spawned eggs when used in Lake Ontario by Chuck Krueger of Cornell University, they were not successful on Julian's Reef, despite an extensive four-year effort involving the deployment of over 2,000 egg nets. As yet, no spawned lake trout eggs have been recovered from Julian's Reef.

Failure to collect spawned eggs is puzzling in view of the fact that mature and gravid adult lake trout aggregate over the reef each fall. Possibly the spawning lake trout are highly selective about spawning sites and that despite the extent of our efforts our egg nets missed the specific areas chosen by the fish.

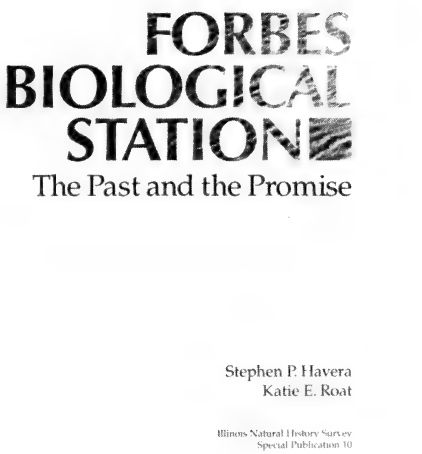
Historical information presented here was derived from *A strategy for reestablishing self-sustaining lake trout stocks in Illinois waters of Lake Michigan,"* by C. E. Coberly and R. M. Horrall. Work with egg nets in Lake Michigan was supported by Federal Aid in Sport Fish Restoration.

By *William Horns, Section of Aquatic Biiology*

Recent Survey Publication:

Havera, S. P., and K. E. Roat. 1989. Forbes Biological Station: The Past and the Promise. Illinois Natural History Survey Special Publication 10. 24p.

Special Publication 10 of the Illinois Natural History Survey, *Forbes Biological Station: The Past and the Promise,* describes the past and current staff and their studies at the first inland aquatic biological station in the world. Authors Stephen P. Havera and Katie E. Roat include in this publication the reasons why Stephen A. Forbes established a permanent field station on the shores of an



Illinois River backwater lake near Havana in 1894 and the main points of interest thereafter. Forbes is known to many as the "Father of Ecology" and was the first Chief of the Natural History Survey.

The establishment of this biological station, first named the University of Illinois Biological Experiment Station and later referred to as the Illinois Biological Station, allowed Forbes and his staff to pursue the "continuous investigation of the aquatic life of the Illinois River and its dependent waters." This station, originally consisting of a chartered cabin boat stationed on Quiver Lake and three rented rooms in Havana, and the research conducted by the station's staff over 95 years have permitted the Illinois River to be referred to as the "most studied" river in the world.

During the span of years beginning with Forbes' first studying the Illinois River in 1876, continuing through the establishment of the biological station in 1894, the construction of a permanent building in 1939, and the expansion and remodeling of that building in 1988, Survey scientists have documented man's effects on an essentially pristine river. The special publication on the Forbes Biological Station is an entertaining journey of words and pictures through almost 100 years of science conducted at a unique establishment.

By *Stephen P. Havera, Wildlife Research Section*

Mussels of the Wabash River Drainage

The Wabash River, the longest free-flowing river in the eastern United States, and its floodplain contain abundant fish and wildlife. It is one of the few large rivers in the country that remain unimpounded and unchannelized throughout most of its length. From the time that Thomas Say, one of Americas's first naturalists, arrived in New Harmony, Indiana, in the early 1800's to the present, biologists have been interested in the diverse and abundant freshwater mussel fauna of the Wabash River. Approximately 75 species of mussels have been reported from the Wabash River; unfortunately, data collected in the past two years indicate that the number of species now present is only about 37, a 51% decrease in the number of species present historically.

Mussels are filter feeders that must continuously pass water through their gills to survive and, thus they are excellent indicators of water quality. These animals are normally long-lived and sedentary, and they are extremely susceptible to the cumulative effects of siltation and other forms of pollution.

In order to provide protection for this important part of our natural heritage, periodic stream surveys are needed to document changes in mussel populations. By looking at the number of individuals of each species found today

The rabbitsfoot (*Quadrula cylindrica*), one of the endangered mussel species found in the Wabash River Drainage (photo by Kevin S. Cummings).

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and comparing them to data from past studies, we can estimate changes that have occurred over the years. Recent surveys have indicated that many mussels that were widespread and common in the Midwest have been drastically reduced in number, or are thought to be extinct.

In 1987, a three-year study of the mussels of the Wabash River and two of its major tributaries, the White and Tippecanoe rivers, was initiated. The objectives of the study are to document the distribution and abundance of mussels present with a particular emphasis on endangered species. The project is a cooperative effort between the Illinois Natural History Survey, the Indiana Department of Natural Resources Division of Nongame and Endangered Species, and the U.S. Fish and Wildlife Service. Surveys have been completed on the Wabash and Tippecanoe rivers, and work began on the White River in the summer of 1989.

Fifty-three sites on the Wabash River and 16 sites on the Tippecanoe River were systematically sampled from spring 1987 to late summer 1988. Shells of 62 species were collected in the Wabash River, but only 37 species were found alive. The Wabash River collections were dominated by three species which accounted for over 64% of the 3,784 live mussels found.

The Tippecanoe River is a medium-sized tributary of the Wabash River in northern Indiana. It is one of the finest streams remaining in the upper Midwest with respect to mussels and contains many rare species. Forty species were found in the Tippecanoe River and, of those, 34 were found alive. The three most abundant species accounted for 33% of the 1,499 live mussels found.

Shells of 20 rare, threatened, or endangered species were found, but only six were found alive. These six include the federally endangered fat pocketbook (*Potamilus capax*); the federal candidate species fanshell (*Cyprogenia stegaria*), clubshell (*Pleurobema clava*), purple lilliput (*Toxolasma lividus*), the state-listed sheepnose (*Plethobasus cyphyus*), and rabbitsfoot (*Quadrula cylindrica*).

This survey and others like it around the eastern United States indicate that we have lost or are in danger of losing many of our native mussels. The decline in mussel populations is probably due to a combination of factors but siltation seems to be the primary cause. Stronger soil conservation measures are needed in lands bordering our streams to prevent surface run-off and to help curtail erosion. Increased controls on the commercial harvest of these animals may also be warranted if we are serious about protecting this valuable resource.

By *Kevin S. Cummings, Section of Faunistic Surveys and Insect Identification*

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Of Channel Catfish and the Illinois River

The channel catfish (*Ictalurus punctatus*) is important to sport fishing as well as to the commercial species in Illinois. Fishing pressure has been increasing in recent years to the point where 40% of the total stream sport fishing in Illinois is for catfish. Suitable stream and river habitat has been declining over that same period. The long-term fisheries strategy for Illinois streams and rivers calls for enhancement of degraded habitat, prevention of further degradation, and compensation for loss and damage that cannot be prevented.

Commercial navigation has the potential to impact channel catfish and catfish habitat. An increase in barge traffic on the Illinois River is predicted into the 21st century with completion of the second lock at Alton. Potential impacts of navigation on channel catfish need to be documented so that mitigation can be planned.

From July to September 1987, locks at Peoria and LaGrange were closed for rehabilitation, halting commercial navigation on a stretch of the Illinois River. The closing provided a unique opportunity to monitor movements and habitat use by channel catfish in the absence of barge traffic and then with barge traffic in 1988. In a study initiated in June of 1987, investigators used radio telemetry to determine movement patterns, habitat use, and effects of navigation on channel catfish.

Researchers Brian Todd and Frank Dillon, of the River Research Laboratory at the Forbes Biological Station, collected channel catfish from the Illinois River and its tributaries around Havana. Radio transmitters were implanted surgically in the abdominal cavities of 38 channel catfish in 1987 and 48 in 1988. Radio-tagged fish were usually located by boat. However, fish that were lost were located using an airplane equipped with telemetry-receiving equipment.

Brian L. Todd, at the helm, and Frank S. Dillon, right, in radio-tracking boat on the Illinois River.

The fish occupied backwaters whenever water levels were high enough for the fish to enter them from the channel. During the drought of 1988, however, water levels were so low that fish were forced into the deeper areas adjacent to the channel. The results indicated channel catfish prefer more protected side channels and areas adjacent to the navigation channel rather than the navigation channel itself. There was no difference between day and night in selections of habitat.

Fish moved most in the summer of 1987 and in late spring/early summer in 1988 and were also active when water levels fluctuated. On a daily basis, channel catfish were most active from 4:00 p.m. to midnight. Most of the fish moved less than 4 miles. However, one fish moved upstream 7 miles and then moved downstream 29 miles. Channel catfish in or near the navigation channel moved an average of 80 feet in response to 52% of the tow passages monitored.

With the information from this study, recommendations regarding habitat protection and enhancement will be made to the Illinois Department of Conservation and the Army Corps of Engineers to insure both good fishing and commercial navigation. If navigation adversely affects channel catfish populations, corrective measures might include restoration of side channels or backwaters which are protected from barge traffic but have silted in or filled with dredge spoil.

This study by the Natural History Survey is partially supported by funds from an excise tax on sport fishing equipment for sport fish restoration, administered by the Illinois Department of Conservation.

By *Brian L. Todd, Frank S.Dillon, and Richard E. Sparks, Center for Aquatic Ecology*

Jones, A. G. 1989. *Aster* and *Brachyactis* in Illinois. Illinois Natural History Survey Bulletin 34(2): 139–194.

Some of the most common and attractive wildflowers in the Illinois landscape during autumn belong to the genus *Aster* of the sunflower or composite family. There are many different kinds of asters in the State, and botanists are often frustrated by the difficulty of identifying them. Dr. Almut G. Jones, Curator of the Herbarium and Associate Professor of Plant Biology at the University of Illinois, is one of the leading authorities on the classification of the asters of North America. The Illinois Natural History Survey is pleased that she has prepared an account of the asters of Illinois, entitled *Aster and Brachyactis in Illinois,* that has just been published as Illinois Natural History Survey Bulletin, Volume 34, Article 2.

DR. ALMUT G. JONES

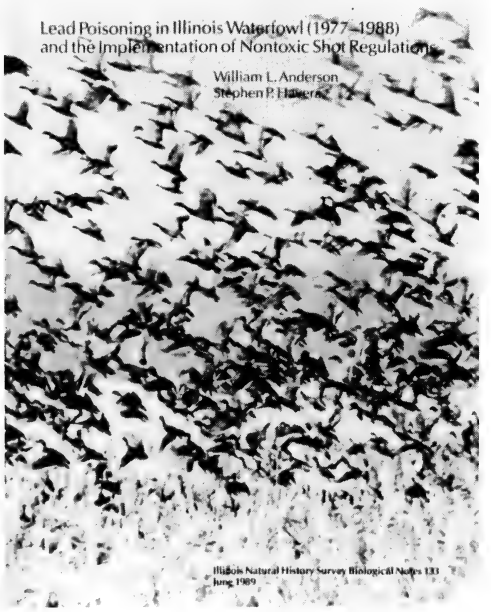
The publication presents a taxonomic treatment of all of the asters native or naturalized in Illinois, with a key to their identification. For each species there are both scientific and common names, a list of other scientific names that have been used in the past for the species, a detailed description, a map showing the distribution of the species in Illinois by county, comments based on Dr. Jones detailed knowledge of asters, and information on flowering times, ecology, generalized distribution, and chromosome number. This publication will be especially useful to botanists, ecologists, and naturalists who frequently encounter asters as part of their field studies. Copies are available at a cost of $3.00.

By *Kenneth R. Robertson, Center for Biodiversity*

Lead Poisoning in Illinois Waterfowl and the Implementation of Nontoxic Shot Regulations

Lead poisoning has caused mortality in waterfowl for more than a century. Waterfowl and other birds contract the disease by eating lead shot while feeding. The U. S. Fish and Wildlife Service initiated limited use of nontoxic (steel) shot for hunting waterfowl in the Atlantic Flyway in 1976, in the Mississippi Flyway in 1977, and in the Central and Pacific flyways in 1978. These regulations prompted studies in many states, including Illinois, to determine the prevalence of lead poisoning in waterfowl. The requirement to use steel shot motivated some hunters to resist the use of steel shot, with a result that restrictive legislation was passed at the state and national levels and law suits were filed.

The Natural History Survey conducted the first formal studies of lead poisoning in waterfowl in the 1950s through the efforts of researchers Frank C. Bellrose and James S. Jordan. The Natural History Survey's concern with the problem of lead poisoning in waterfowl has resulted in a series of ongoing studies. As a result of some of the most recent studies, researchers William L. Anderson and Stephen P. Havera have published *Lead poisoning in Illinois waterfowl (1977–1988) and the implementation of nontoxic shot regulations.* The publication reports their findings on lead poisoning and documents the incorporation of the studies in Illinois and elsewhere into complex policy-making decisions over the past 10 years–the critical decade of transition in the adoption of nontoxic regulations for hunting waterfowl in the United States.



The researchers studied lead poisoning in waterfowl in Illinois by determining the incidence of shot in soil and sediment, by examining gizzards for ingested shot, by analyzing blood for lead and protoporphyrin and livers for lead, and by confirming die-offs from the disease. Spent shot averaged 37,700 pellets per acre in soil and sediment in one subimpoundment at Rend Lake. Both lead and steel shot were found in an average of 5.9% of the gizzards of 13,779 mallards, 6.9% of 1,385 gizzards of lesser scaups, and in 5.6% of 887 Canada geese. Steel averaged 20.9% of the pellets found in mallards throughout the State and 46.2% on areas where nontoxic shot was used extensively. Amounts of lead above background levels in livers and of protoporphyrin in blood (which indirectly indicates the amount of lead) were similar to incidences of lead shot in gizzards; incidences of above-background concentrations of lead in blood averaged 6 to 10 times greater than the incidences of ingested shot. The prevalence of lead poisoning in waterfowl was 5.0% or higher in most waterfowl examined in Illinois. Thirteen cases of lead poisoning die-offs of waterfowl were documented in Illinois from 1977 through 1988.

Two laws — one state and one federal — hampered the regulations for the use of nontoxic shot in Illinois. The "Stevens Amendment," which required the U.S. Fish and Wildlife Service to secure the approval of the states before enforcing nontoxic shot zones in a state, and an Illinois law, which placed limits on the Illinois Department of Conservation regarding the use of steel shot for hunting waterfowl, both severely restricted the latitude of the Illinois Department of Conservation in establishing nontoxic shot zones. Six law suits in

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state and federal courts unsuccessfully challenged state and federal nontoxic shot regulations, and one successfully argued for the expansion of nontoxic shot zones to protect the federally endangered bald eagle from lead poisoning as a result of feeding on sick and crippled waterfowl that contained lead shot. In 1986, the U.S. Fish and Wildlife Service presented plans for a nationwide phaseout of lead shot for waterfowl hunting that will be fully in place by 1991. This policy states that "If states do not approve nontoxic shot zones when current FWS guidelines and criteria indicate that such zones are necessary to protect migratory birds, the FWS will not open the area to waterfowl and coot hunting. . . ." The Illinois law at that time came within 7 days of preventing the opening of some areas to waterfowl hunting in Illinois in 1987. The Illinois law has since been changed to allow compliance with the federal regulations. As was demonstrated in this case, narrowly conceived legislation can be detrimental to sport hunting and to the successful management of wildlife resources.

Copies of the publication by Anderson and Havera are available from the Illinois Natural History Survey, Distribution Center, Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820. Request Biological Notes 133. The cost is $2.00 per copy. Make checks or money orders payable to the Illinois Natural History Survey.

By *Glen C. Sanderson, Director, Center for Wildlife Ecology*

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World Bibliography of Soybean Entomology

The value of the Illinois soybean crop exceeds 2 billion dollars per year. To protect this immense resource from losses caused by pests, farmers must adopt control measures that should be specific to each type of pest. Researchers must gather the scientific information upon which these control measures are based. Quick access to information is a key factor for the success of pest control programs. Because of the importance of soybean in Illinois, the Illinois Natural History Survey, Center for Economic Entomology, established in 1969 the Soybean Insect Research Information Center (SIRIC), to compile, organize, and store the worldwide literature on insects associated with soybean. In 1988 the University of Illinois College of Agriculture sponsored the publication of the *World Bibliography of Soybean Entomology* authored by SIRIC Librarian Jenny Kogan, Survey Entomologists Marcos Kogan and Charles Helm, with the assistance of the Survey Computer Specialist Ellen Brewer.

Publication of the *World Bibliography of Soybean Entomology,* in two volumes, represents the culmination of nearly 10 years of intensive bibliographic research. Over 5,000 documents have been collected, classified using a thesaurus of hierarchical key words, and processed for electronic storage and retrieval.

Volume I contains an introduction with a list of major pest species in each of six production regions of the world and a bibliometric study of the literature. Criteria for inclusion of documents and the structure of the bibliography are explained in the introduction. Bibliographic entries appear in alphabetical order by author(s). Each entry is followed by a string of keywords that reflects the subject contents. These key words are also used in the subject indexes in Volume II.

Pictured at the World Soybean Research Conference held in Buenos Aires recently are Jorge Aragon, Argentina, who was a part of the Entomology Scientific Committee; Charles Helm and Jenny Kogan, two of the authors of the prize-winning book; and Dan Fischer, Survey staff member who also attended the Conference. Lloyd LeMere created the poster display for the Conference.

Volume II contains six indexes that refer to the sequentially numbered entries:

1. *Author Index.* An alphabetical list of all authors. Users can retrieve the entire contribution of a given author, whether that author appears as the senior or junior author.

2. *Geographic Index.* A list of the countries in which the research was done or that are mentioned in the entries.

3. *Language Index.* A list by language of all entries, excluding those printed in English.

4. *Host Plant Index.* A hierarchical list

of plants (family and genus) mentioned in the entries.

5. *Taxonomic Index.* A hierarchical list of arthropods (order, family, and genus).

6. *General Descriptor Index.* A list of subject descriptors hierarchically organized. A subindex for these descriptors is organized alphabetically.

Taken together, the geographic and the language indexes indicate the international scope of the bibliography. References represent the literature from 87 countries in 24 languages.

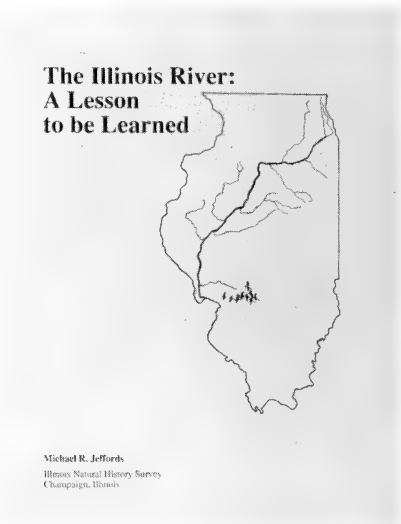
The host plant, arthropod taxonomic, and general descriptors indexes are hierarchically organized. To facilitate use of the hierarchical indexes there is an alphabetic index of taxa and general descriptors, each followed by the higher level hierarchies and the page of the index volume where the descriptor appears. Thus, in searching for *Cerotoma trifurcata* one will find in the alphabetical index, the entry: *Cerotoma trifurcata* — Coleoptera: Chrysomelidae, p. 68. On page 68, *Cerotoma trifurcata* appears followed by the numbers of the citations that contain reference to that species. The indexes are a unique feature of this bibliography. Volume II also includes lists of abbreviations for all periodical titles in the bibliography.

The *World Bibliography of Soybean Entomology* has been compiled as part of the SIRIC operations. SIRIC is supported by the University of Illinois Agricultural Experiment Station, the Illinois Natural History Survey, and the American Soybean Association. The *World Bibliography of Soybean Entomology* was the recipient of the 1989 Oberly Award for Bibliographic Excellence in the Agricultural and Related Sciences. The award is made by the American Library Association. Copies of the bibliography are being sold by the University of Illinois, Office of Agricultural Publications, 67 Mumford Hall, 1301 W. Gregory Drive, Urbana, IL 61801. Price of the 2-volume set is $65.00.

By *Jenny Kogan and Marcos Kogan*
Center for Economic Entomology

The Illinois River:
A Lesson to be Learned

A new middle school curriculum *The Illinois River: a lesson to be learned* was produced in conjunction with the State Museum's traveling exhibit *Harvesting the River.* The exhibit is housed on a refurbished towboat and will travel the Illinois and Mississippi rivers this fall. The curriculum, along with other educational materials, is to be distributed to teachers along the route. A second, expanded edition of the curriculum was completed by the Survey for inclusion in a packet of educational materials distributed to teachers by the Sun Foundation to promote the November program by world explorer Jean-Michel Cousteau in Peoria.



The curriculum focuses on the historical events that caused the decline of the Illinois River, the overall effects of human activites on the past and present river system, and on the general biology of the river. The activities, complete with background information and bibliography, are written for teachers of grades 5-8 and designed to supplement existing materials on aquatic biology and ecology. Copies of *The Illinois River: a lesson to be learned* may be obtained by writing to the Illinois Natural History Survey. Cost of the publication is 50 cents.

By *Michael Jeffords*
Center for Economic Entomology

Deer seek refuge in upland forest area near the Illinois River in northern part of the State.

Winter Refuges — The Key to Survival for Farmland Deer

Deer in the Midwest farm belt may be characterized as well-fed, healthy, fertile, short-lived (on hunted ranges), and living in a relatively benign climate. Deer numbers have been increasing throughout Illinois because females have high reproductive rates and high annual survival. Males die at higher rates than females because of hunter's preferences for antlered males and because their seasonal movements are extensive, usually exceeding the boundaries of most refuges, particularly during the fall months.

In central and northern Illinois, where forest cover is scarce, seasonal deer abundance and dispersion throughout the landscape depends on forest characteristics. Larger forest areas (more than 400 ha) and areas closed to firearm deer hunting (where annual mortality rates are low) are occupied by deer throughout the year. Smaller forests (woodlots and narrow riverine forests) are occupied by deer in spring, summer, and fall but are vacated in winter because deer are killed by hunters or because the forests are not large enough to offer winter protection.

The rate of local deer extinctions and recolonizations of "islands" of forest scattered within the sea of agricultural crops characteristic of the Midwest farm belt depends upon the distance from a refuge, the size and composition of the forest (chiefly a measure of cover value), and predation pressures (primarily human patterns). Migrations (movement away from a site in the spring and subsequent return to the same area in the fall, a behavior of yearling and older females) and dispersals (a one-way movement away from their natal areas, a behavior of fawns of both sexes and some yearling females) allow deer to reoccupy these marginal habitats each year. In northern Illinois, deer movements between widely scattered summer and winter ranges have been recognized since the 1940's, which was prior to modern day firearm deer hunting.

Winter movements by deer to traditionally used sites are frequently a learned behavior, passed on to successive generations through association of fawns and older relatives. Deer are organized socially as maternally related clans, with a matriarch sharing her home range with successive generations of fawns. Thus, the protection offered by secure wintering sites are necessary for successive generations of deer to live long enough to develop traditions of use for specific sites. Use of a particular area by each deer depends on its location of birth and its mother's seasonal movement patterns. Because of high deer mortality in small woodlots, a tradition of seasonal movements between the same winter

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and summer ranges is frequently impossible. However, deer that are born within refuges or that disperse to refuges frequently exhibit these seasonal movements.

One of the key features of the resurgence of deer numbers in central and northern Illinois has been the presence of private and publicly owned sites offering deer protection in winter. Deer require upland, unpastured forested sites that offer sufficient diurnal cover for winter protection. They avoid frequently flooded bottomland forests and forested pastures in winter. Unfortunately, upland forests are also favored by humans as sites for new housing, or for conversiion to agricultural uses. Less than 55% of the wintering sites thus far identified in 46 counties of central and northern Illinois are protected by public ownership. At present the effects on deer of the continuing loss of upland habitat at many of the unprotected, traditionally used wintering sites goes unnoticed, because deer are currently abundant throughout the State. However, a continuing loss of suitable winter cover on these wintering sites will eventually reduce deer numbers and will also reduce the number of potential dispersing deer available to restock hunter depleted ranges surrounding each wintering site. Deer are adapted to use any upland habitat (including grasslands, marshes, strip-mined areas, as well as forest) that offers diurnal cover, but there are limits to their tolerance of limited available cover.

Most of the important sites used as winter cover by deer in central and northern Illinois have been identified. Those sites not protected by public ownership are vulnerable to conversion to land uses not compatible with continued deer presence in winter. A recognition of their importance to deer (and to many other species of wildlife as well as their watershed protection values) will aid in their continued protection. Ideally, a system of protected forests or grasslands with connecting corridors of cover will be developed along the major watersheds in central and northern Illinois, offering protection for Illinois's natural resources and providing opportunities for the public to enjoy them.

By *Charles M. Nixon*
Center for Wildlife Ecology

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Male Minnows Build Spawning Nests

With over 2,070 species, the minnow family (Cyrinidae) is the largest family of fishes in the world. The more than 220 species that occur in North America are often the most abundant fishes in streams and lakes. Very little is known about this group of ecologically important freshwater fishes.

A group of eastern North American minnows once called Awadosi, or stone carriers, by the Indians of the Hudson Bay region is particularly interesting. These fishes, which are known as chubs today, are unique among North American minnows in that they build spawning nests in the gravel substrate of streams. The nest of the fallfish *(Semotilus corporalis)*, the largest species of nest builder, can be six feet in diameter, three feet high, and contain several thousand stones. Nests are usually built by one male, who uses his mouth to carry stones to the nest, or excavate them from a pit.

Only about 8% of North American minnows build nests for spawning. Species of nest builders are found in genera *Luxilus, Camostoma, Semotilus, Nocomis, and Exoglossum.*

With the exception of *Exoglossum,* nest-building minnows exhibit strong sexual dimorphism. Males are larger and more brightly colored than females and develop keratinized structures, called breeding tubercles, on the head, body, and fins.The largest breeding tubercles are found on the head and are extremely large in some species. Functions of breeding tubercles on the head are thought to include display, defense, and stimulation of females. Tubercles on the body and fins are thought to assist in holding or maintaining contact with females during spawning.

Three types of nest-building behavior have evolved in several groups of eastern North American minnows: pit-building, pit-ridge building, and mound-building. Striped shiners *(Luxilus chrysocephalus)* and stonerollers *(Campostoma anomalum)*, both common in Illinois, are examples of fishes that build simple pits in gravel areas for spawning. Small circular depressions are formed by males who dig into the substrate and push material aside with their snouts and, in stonerollers, remove small stones with their mouths. Males are aggressive and defend positions over pits. Females congregate nearby and enter the pits individually. Spawning occurs as one or more males converge on a female in a pit. These species may spawn in association with each other or over the nests of other species of minnows.

The creek chub *(Semotilus atromaculatus)*, one of the most common fish species in Illinois, spawns in pit-ridge nests constructed by males. Males excavate pits in gravel runs by removing stones with their mouths and piling them

Breeding tubercles are very evident on male minnow carrying stones to nest he is building (photo by Carol E. Johnston).

immediately upstream. Spawning occurs when a female enters the pit, and eggs are covered with substrate by the male who then extends the pit downstream. Eventually the nest becomes a long ridge of gravel. Single male creek chubs build nests and guard them from intruders, especially conspecific males. Such territoriality and the apparent shortage of suitable nest sites result in a complex social system and aggression among breeding males. Challenges by similarly sized males result in complex displays called parallel swims. Smaller males that attempt to take over nests are driven away, often by a display of head tubercles by the resident male. Many males do not build their own nests, but instead act as satellites, waiting for opportunities to temporarily occupy the nests of territorial males and spawn.

Gravel mound nests are constructed by two groups of minnows: cutlips minnows *(Exoglossum)* and chubs *(Nocomis)*. Male chubs begin nest construction by excavating a pit in gravel substrate of a stream. The pit is then covered with stones the male carries to the site in his mouth, and a large mound is constructed. Spawning occurs in small pits dug on top of the mound by the male. Nest construction in cutlips minnows is similar except the nest is not started as a pit, and spawning occurs on the upstream slope of the mound rather than in pits dug by the male. Although males of all other nest-building minnows develop conspicuous breeding tubercles, male *Exoglossum* do not.

Little is known about the breeding behavior and social systems of nest-building minnows. Observations on several species of nest builders are being made during the breeding season by researcher Carol E. Johnston in order to gain an understanding of various aspects of the behavior of these species. Special attention to the behavior of males is being made so that a comparative study of the social systems of nest-building species can be made.

Often the nests of minnows are used for spawning by other species of minnows. This habit, termed nest association, is especially common over the gravel mound nests of *Nocomis* and *Exoglossum*. Research is underway to determine the nature of this relationship. Are nest associates parasites, or does the host derive some benefit from nest association? How did this behavior evolve? Through field observations and experimentation a better understanding of nest building, nest association, and the interrelationships of the species involved will be gained. In addition, life history information is being gathered on species of minnows whose habits are virtually unknown. Such information aids in the preservation of the biodiversity of natural systems.

By *Carol E. Johnston*
Center for Biodiversity

Fisheries Research Programs on Lake Michigan

Of Illinois' 1.5 million acres of surface waters, two-thirds are contained in the Illinois portion of Lake Michigan. Lake Michigan's fish populations have changed dramatically over the past 50 years because of competition from introduced species, commercial fishing, predation, disease, and environmental degradation. Therefore, management of fish species in Lake Michigan presents many challenges. To provide research data for management decisions, the Survey's Lake Michigan Laboratory at Zion is conducting studies on such important species as yellow perch, lake trout, and chinook salmon.

Yellow perch is important to both sport and commercial fisheries in Illinois. During the 1980s, the sport fishery for yellow perch in the Illinois waters of Lake Michigan grew to more than 1.7 million harvested annually. The annual commercial harvest increased from 46,000 pounds in 1979 to over 150,000 pounds in recent years. To assess the yellow perch fishery and to determine the effects of a rejuventated fishery on sport fishing, Survey scientists are tagging 10,000–15,000 yellow perch annually. Through recaptured tagged fish, biologists will be able to assess movements and the size of the fishable population of yellow perch.

Over the past 30 years, abundance and growth of yellow perch have fluctuated widely and unpredictably, possi-

bly because of predation by alewives and competition for food resources. Alewives eat large numbers of small yellow perch. Therefore, scientists are investigating the timing and magnitude of yellow perch hatches and the timing and extent of alewife predation on newly hatched yellow perch.

When young yellow perch are abundant, they graze heavily on zooplankton and may deplete that food resource, thereby limiting their own growth. Slow growth, in turn, may affect abundance because the period when yellow perch are vulnerable to predation by alewives is extended. Researchers are monitoring zooplankton populations and growth rates of yellow perch in two areas of Lake Michigan to fully determine the effects of competition for food resources.

Lake trout maintained a natural population in Lake Michigan until about 1950, when they were eliminated as a result of lamprey parasitism, competition, and overexploitation. Over 30 million have been stocked in the Great Lakes since 1986 in an effort to reestablish self-sustaining populations. More than 1 million lake trout were stocked over Julian's Reef in the Illinois portion of Lake Michigan. However, evidence of natural reproduction by stocked trout has been scant. Using a technique that has been successful in Lake Ontario, Survey researchers attempted to recover spawned eggs from Julian's Reef from 1985 through 1988. Although mature and gravid lake trout aggregate at Julian's Reef in the fall, no eggs were recovered. Because lake trout are highly selective in choosing spawning sites, scientists speculate they may have missed the spawning grounds chosen by the fish.

Chinook salmon were introduced into Lake Michigan to help control the alewife population and are now a popular sport fish. At stocking time, chinook salmon may be vulnerable to predation by adult yellow perch. The current abundance of yellow perch in Lake Michigan, therefore, may contribute to recent poor sport fishing for chinook salmon. Researchers are collecting yellow perch in the vicinity of chinook salmon stockings; they later dissect the fish and examine stomach contents for the presence of yearling chinook salmon. These data will help to evaluate the impact of yellow perch on the salmon fishery.

These research projects are jointly funded by the Survey, the U.S. Fish and Wildlife Service, and the Illinois Department of Conservation through the Federal Aid in the Sport Fish Restoration Program and the Illinois/Indiana Sea Grant Program.

By *William H. Horns and Jana L. Waite*
Center for Aquatic Ecology

Insect Defoliation/Weed Competition Interactions in Soybeans

Many factors play a role in limiting soybean yields below their potentials. Insect, weed, disease, and nematode pests contribute to yield losses in varying degrees in different growing regions. Climatic and soil factors such as precipitation and nutrient problems can further confound the effects of any particular pest. However, pests rarely occur in isolated, pure populations exclusive of other pest species. Consequently, complications arise when growers are faced with the combined impacts of insects and weeds, nematodes, or diseases, or even three- and four-way combinations of these yield-limiting factors. Add to this the economics of production, protection, and marketing and it is easy to become overwhelmed by the magnitude of designing sound pest management recommendations.

Survey scientists have undertaken a multidisciplinary research effort involving the combined effects of weed com-

Soybean looper, *Pseudoplusia includens*, larvae (photo by Charles Helm).

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petition and insect-produced defoliation on soybean growth and yield to improve our understanding of pest complexes within the soybean ecosystem. Using methodologies previously described in Natural History Survey Reports (No. 221, November 1982), Survey scientists have gathered several years of data on 1) the single effects of competition by two different weed species, either cocklebur, *Xanthium pennsylvanicum,* or velvetleaf, *Abutilon theophrasti,* 2) the single effect of defoliation by populations of soybean looper, *Pseudoplusia includens,* larvae, and 3) the combined effects of concurrent weed competition and defoliation at various intensity levels.

Actual interactions between weed competition and defoliation have been rather small and somewhat variable. Damage by the pest complex, with either cocklebur or velvetleaf as the weed competitor, at times showed clear additive effects. In other instances, although damage by the complex was not truly additive, the combined effects were still greater than the individual effects of either weed competition or defoliation.

Although these studies have not yet produced multiple-pest decision charts or new thresholds for insect-weed pest complexes, new insights have been gained nonetheless. Results of these controlled experiments do not suggest that current control decisions for either class of pest need drastic revisions; that is, conventional treatment thresholds for insect defoliation appear valid under conditions of moderate weed competition. It has been observed in some years that velvetleaf biomass increased when soybean was heavily defoliated, suggesting that defoliated soybean is perhaps a poorer competitor with velvetleaf than is undefoliated soybean.

Further experimental work is needed on pest-complex/soybean growth-yield interactions. Until these interactions are better understood, integrated control decisions remain best-guess estimates, and some of the barriers to improved soybean yields and lowered production costs are likely to remain. As more information from studies such as this becomes available, it will be used in the development and validation of simulation models for multiple pests in soybeans in order to better assess the complexities of comprehensive crop and pest management.

By *Charles Helm and Marcos Kogan*
Center for Economic Entomology

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The Biodiversity of Illinois and The Illinois Natural History Survey Collections

Biodiversity, or the variety of life in all its forms, has been the primary subject of the Illinois Natural History Survey since its founding in 1858. A recent reorganization of the Survey resulted in two principal study groups, one dealing with plants and the other with animals, being combined into the Center for Biodiversity. The mission of the new unit is to acquire and apply information pertaining to the diversity of life in order to protect, manage, and develop the biotic resources of Illinois in accordance with long-term environmental goals.

Kathryn McGiffen, Manager of the Insect Collection, is pictured working with specimens (photo by Delfina Colby, *Champaign News-Gazette*).

Activities of the Center include conducting field surveys to determine the abundance, distribution, and ecological relationships of organisms; analyzing the roles of biotic and abiotic components of the environment in maintaining and altering the abundance and distributions of organisms; studying the systematic relationships of organisms to ensure their proper classification and identification; and maintaining and enhancing the State's research collections of organisms and associated databases. The Center is concerned with the recognition of species, habitats, and ecosystems that appear to be endangered and the development of conservation strategies for their protection.

Along with changes in the environment come changes in distributions of populations, and time-related collections are important measurements of these changes. A major goal of the public today is to protect species as they approach extinction (endangered species, such as the bald eagle and the lake sturgeon). Collections often provide the only record of the historic distribution and abundance of species and tell us, through comparisons of past and present data, which species are doing well, which have always been rare, and which are disappearing the most rapidly. For extinct species, our only source of additional information comes from preserved specimens and, when available, the fossil record.

In 1858, the year of the formation of the Natural History Society of Illinois, later to become the State Laboratory of Natural History and then the Illinois Natural History Survey, the only large natural history collection in the Midwest was that accumulated by Robert Kennicott and housed at Northwestern University. Stephen A. Forbes, first Chief of the Illinois Natural History Survey, believed that a reference collection for identification of specimens was one of the most important tools of the biologist, and he strongly encouraged collection activities by Survey staff. The Survey's collections grew quickly and now are among the oldest, most comprehensive collections of North America. The antiquity of the Survey's collections is their greatest strength.

Another feature adding to the importance of the collections is the large number of type specimens. Type specimens, or types, are the specimens originally examined by the person describing a species and are the specimens to which a name is permanently attached. Thus, types serve as important references in many aspects of biological research.

Fourteen collections are housed at the Survey. The Insect Collection is the largest with almost 6,000,000 specimens; the Fish Collection has about 650,000 specimens; several other collections have between 100,000 and 200,000 specimens. The geographic scope of the collections ranges from Illinois to worldwide. Typically, they have a thorough representation of Illinois material and supplementary national or international representation. Some are growing rapidly, such as the Insect Collection (which adds about 20,000–30,000 specimens a year); others (e.g., Amphibian and Reptile Collection) are growing slowly because of the lack of a systematics program or lack of funding.

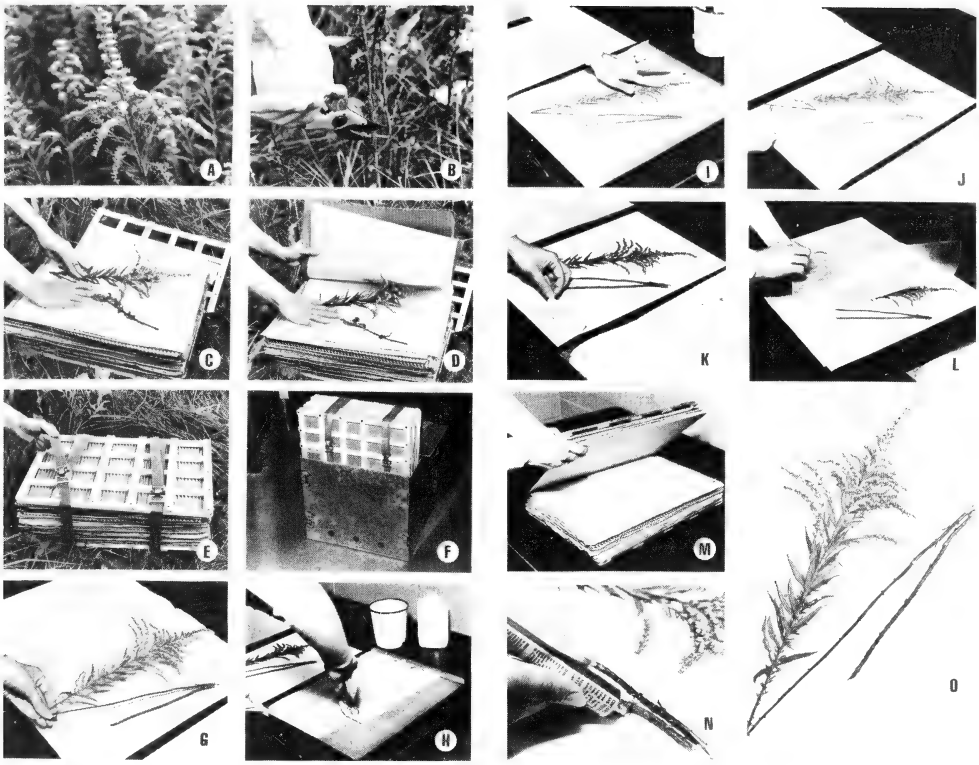
During the past five years, an average of 125 scientists a year have visited the Survey to study the collections. Nearly 17,000 specimens a year are loaned to other institutions. The National Science Foundation recognizes the importance of the Survey's collections to the scientific community and has provided two large grants in the past five years to support their care.

Data associated with the collections, in combination with the expertise of the scientists developing the collections, have been used to recognize biologically outstanding natural areas, to formulate management plans for habitats and species, and to develop accurate and meaningful lists of endangered species, of harmful species, and of potentially manageable species.

VASCULAR PLANTS

The Illinois Natural History Survey has maintained plant collections since its inception in 1858. Because of the Survey's close association with the University of Illinois, these early collections were transferred to the herbarium of the University in 1921. In 1927, Survey staff established a program to accumulate a collection of plants of the State, and in 1931 the first specimens were collected and deposited in the new Survey herbarium. During most of the early years of the new herbarium, the collection of plant specimens was the responsibility of the plant pathologists. The herbarium contained about 17,400 specimens in 1946, when Robert A. Evers joined the staff and was placed in charge of botanical surveys. Evers was a prolific collector during his nearly 30 years with the Survey, and he personally collected over 116,000 specimens. Currently, the herbarium contains approximately 173,000 specimens. It is the third largest herbarium in Illinois and one of the largest herbaria supported by a state agency in the United States.

The majority of specimens are from Illinois, and coverage is statewide. The emphasis has been on natural habitats, and the collection represents a remarkably complete record of the recent occurrence of plant species in the State. Two important early collections, each with over 1,000 specimens, made in the late 19th and early 20th centuries have been acquired: Charles Robertson's specimens from near Carlinville and L. M. Umbach's specimens from the Chi-



How to make an herbarium specimen: A, the living plant; B, collecting the plant; C, folding the plant to fit into the newsprint; D, folding the newsprint over the plant; E, tightening the straps on the plant press; F, the plant press on a plant drier frame; G, the dried specimen; H, coating a cookie sheet with white glue; I, pressing lightly on the specimen to make sure that glue is transferred to it; J, placing the specimen onto a sheet of mounting paper; K, gluing the label onto the mounting paper; L, covering the glued specimen with a sheet of waxed paper; M, putting the specimen, enclosed in a newsprint sheet, into a plant press for the glue to dry; N, reinforcing stems with straps of household cement; and O, the finished herbarium specimen (photos by Kenneth R. Robertson).

cago region. The herbarium also contains a collection of woody ornamental plants cultivated in Illinois. Non-Illinois specimens are mostly from the southeastern United States, which is floristically like Illinois.

In addition to the Vascular Plant Collection proper, the herbarium contains a collection of approximately 1,500 samples of fruits and seeds and 4,000 specimens of mosses and liverworts from Illinois and Indiana. Ancillary files associated with the herbarium include a card index of distribution by county of all specimens in the herbarium, a file of data on natural areas in the State, an older collection of black and white photographs of plants and natural areas, and a collection of over 10,000 35mm color slides begun by Evers and continued by the present Curator, Kenneth R. Robertson.

A project was begun in 1975 to enter data from herbarium labels into a computer file. Thus far, data from nearly 30,000 specimens have been entered. It is anticipated that computer filing can be completed in the near future, and that data from other herbaria can be put on the system to form a statewide herbarium database. Staff are investigating ways to link the locality information on herbarium labels to the Geographic Information System so that the location of each specimen can be drawn on a computer-generated map, and also to the Illinois Plant Information Network (ILPIN) developed by Louis R. Iverson, which contains a variety of plant-related data.

FUNGI

The fungus collections of the Illinois Natural History Survey and the University of Illinois at Urbana-Champaign had their origin with the rust collection of Arthur B. Seymour and the powdery mildew collection of Thomas J. Burrill. Both of these collections were housed in the Natural History Building at the University of Illinois until 1921 when the plant disease specimens were segregated and became the basis for the Survey's plant disease collection. Efforts at collecting plant disease material were accelerated between 1921 and 1924 and special emphasis was placed on obtaining information on plant diseases in Illinois. By 1924, 18,000 specimens had been added.

Several scientists subsequently contributed to the Survey collection (now referred to as the Survey's Fungus Collection), and it is one of the finest plant disease collections in the Midwest and one of the major collections of fungi in the United States. Gilbert L. Stout was the first plant pathologist at the Survey to devote full time to plant disease survey work in Illinois. He was succeeded by Gideon H. Boewe, whose interest was the distribution, severity, and incidence of plant diseases; Boewe's collections form a large part of the Survey's Fungus Collection. Leo R. Tehon, a pathologist and mycologist, specialized in Ascomycetes and Fungi Imperfecti that cause plant disease, and his collections also form a substantial part of the collection. James C. Carter, an authority on shade and ornamental tree diseases, demonstrated a special interest in pathogenic fungi of woody ornamentals and contributed numerous specimens to the collection. In 1967, J. Leland Crane, present Curator of the Fungus Collection, succeeded Boewe as mycologist, and to date he has contributed over 4,000 specimens of Ascomycetes and Fungi Imperfecti, mostly from decaying substrates in aquatic ecosytems.

Presently, the Survey's Fungus Collection contains 300 type specimens, 800 Myxomycetes, 1,200 lower fungi, 10,000 Ascomycetes, 13,200 Fungi Imperfecti, 5,000 lichens, and 17,000 Basidiomycetes for a total of 47,500 specimens. The specimens are stored dry in packets and filed alphabetically by genus. Computerization of the collection data is underway.

INSECTS

When the Natural History Society of Illinois was formed in 1858, insect collections were maintained by individual scientists. These collections usually represented local fauna or covered only specific groups. An exception was that of Benjamin D. Walsh, the first State Entomologist, whose general collection was an outstanding representation of the insects of Illinois. When the State purchased it in 1870, Walsh's private collection became the first official State collection. William Le Baron, Walsh's successor, selected duplicates for a reference collection in his office and sent the main Walsh collection to the Chicago Academy of Sciences, where it was destroyed in the Chicago fire of 1871. Some of the specimens Le Baron kept in his office are believed to be part of the present Illinois Natural History Survey Insect Collection.

In 1890, during the leadership of Director (and later, Chief) Stephen A. Forbes, the Survey's Insect Collection contained about 5,000 species represented by four pinned specimens each. In addition to the pinned collection, there were about 10,200 bottles and vials of specimens (mostly larvae) and 42,600 pinned duplicates for public school distribution. Theodore H. Frison, who succeeded Forbes as Chief of the Survey, encouraged enlargement of the Insect Collection and enthusiastically supported publication of studies in systematics. Frison organized the staff into work groups or sections, one of which was the Survey Insect Section under the leadership of Herbert H. Ross. The systematic efforts of the Survey were directed by Ross from 1931 to 1969, during which time the Insect Collection became world famous. By 1980, the facilities housing the Insect Collection were no longer adequate for a collection that had grown to include 5,000,000 insects. Under the leadership of Wallace

E. LaBerge, Head of the Section of Faunistic Surveys and Insect Identification from 1979–1989, State and National Science Foundation funds were obtained to install a compacting storage system and to renovate collection rooms.

Today, the Insect Collection contains about 6,000,000 insects and related arthropods, and is the sixth largest insect collection in North America. The collection includes representatives of more than 25,000 insect species and includes primary types for nearly 3,300 insects and 25 related arthropods. Approximately 165,000 related arthropod specimens, including spiders, harvestmen, mites, ticks, scorpions, pseudoscorpions, millipedes, and centipedes, are part of the collection. The collection has developed primarily through the activities of internationally recognized authorities employed by the Survey and by additions acquired through purchases, bequests, and gifts. Recently, collection growth has been at 20,000–30,000 specimens per year. No other collection better represents the midwestern insect fauna, and the holdings in many taxonomic groups are the largest available.

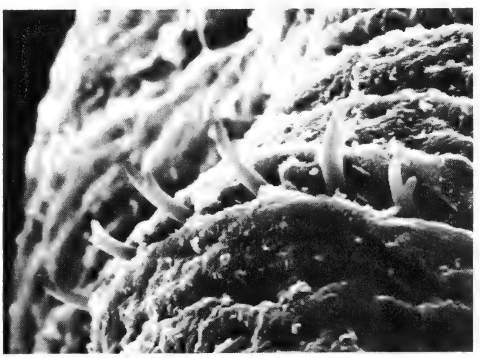
A separate collection maintained by the Survey is the International Collection of Soybean Arthropods. This collection was begun in 1970 to analyze the world soybean fauna, to ascertain the distributional limits of phytophagous species, and to develop an inventory of specimens and data on parasite-host and predator-prey associations. The collection contains more than 150,000 identified and approximately 50,000 unsorted and unidentified specimens.

The permanent curatorial staff associated with the Insect Collection includes four full-time systematic entomologists and a Collection Manager. The curators are Wallace E. LaBerge (bees and ants), Donald W. Webb (flies and scorpionflies), George L. Godfrey (noctuid and notodontid moths and caterpillars), and David J. Voegtlin (aphids). Kathryn C. McGiffen (geometrid moths and caterpillars) is the Collection Manager. Other Survey entomologists (not hired to do systematic work but who are specialists on various taxonomic groups or whose research is allied to systematics) are Allison R. Brigham (aquatic moths), Warren U. Brigham (haliplid beetles), William G. Ruesink (leaf beetles), Michael E. Irwin (stiletto flies), and John K. Bouseman (beetles, solitary bees, and assassin bugs). Affiliate appointments are held by four systematists: Mark B. DuBois (ants), Roderick R. Irwin (butterflies), James G. Sternburg (butterflies and moths), and John D. Unzicker (caddisflies and spiders).

ANNELIDS

The Annelid Collection consists of approximatley 100,000 identified and 25,000 unidentified specimens, including members of the Aphanoneura, Branchiobdellida, Hirudinea, terrestrial and aquatic Oligochaeta, and Polychaeta. The majority of identified material consists of permanent slide mounts. Unidentified material includes permanent slide mounts as well as unmounted specimens in alcohol. Computerization of identifed material will be completed by 1993. To date, the collection contains 65 species of aquatic oligochaetes, 30 species of terrestrial oligochaetes, 32 species of leeches, and several species of Aphanoneura and Branchiobdellida known to occur in Illinois.

Although the collection is worldwide in scope, most of the material is from Illinois and has been collected during the last 16 years. Important collections that have been received as gifts include the Walter J. Harman collection of Illinois terrestrial earthworms. Mark J. Wetzel is the Curator of Annelida.



SEM photomicrograph at 900X of a bundle of six bifurcate chaetae on a tubificid (photo by Kevin S. Cummings).

MOLLUSKS

The Mollusk Collection contains over 100,000 specimens, almost all of which were collected in Illinois and the southeastern United States. The collection is approximately 80% freshwater species (mussels, fingernail clams, and snails) and 20% terrestrial species (snails). Most of the specimens were collected as a result of various faunal surveys conducted by Survey biologists from the late 1800's until the present. The early collections were made by such naturalists as John W. Powell, Robert Kennicott, Richard E. Call, William A. Nason, Frank C. Baker, Robert E. Richardson, and Charles A. Hart.

The freshwater mussels number over 40,000 catalogued and approximately 20,000 uncatalogued specimens. Included among these are representatives of many species now considered rare or endangered by either the state or federal governments. The collection is one of the largest state collections of mussels in the United States.

The main components of the freshwater Mussel Collection are Max R. Matteson's collection of over 20,000 freshwater mussels from a statewide survey conducted in the 1950's, and William C. Starrett's collection of specimens collected for a study entitled "A Survey of the Mussels (Unionacea) of the Illinois River: A Polluted Stream" and published in 1971. These specimens form an important historical database from which biologists can document changes in present-day mussel populations. Recent mussel surveys conducted by Survey biologists as part of an effort to document the statewide distribution of mussels have added many specimens and have helped in preparing a list of endangered mollusks for Illinois.

The snails are about evenly divided between terrestrial and freshwater species, almost all of which were collected over 50 years ago. The largest and best documented assemblage of snails at the Survey was collected by Thural D. Foster and organized by Frank C. Baker as part of his study on the "Landsnails of Illinois" published in 1939.

The dry shells are housed in metal cabinets in wooden drawers and the wet specimens are stored in 70% ethanol. Over 11,000 soft parts (bodies removed from shells) of approximately 50 species have been preserved and are available for study. Each body has been labeled individually using a stainless steel tag and can be matched with the appropriate shell.

About 40% of the collection has been catalogued and computerized. At present this includes only the freshwater mussels. Work will begin soon on automating the fingernail clam and snail data and should be completed in the next few years. The Curator is Kevin S. Cummings.

CRUSTACEA

The Crustacea Collection contains about 50,000 specimens of approximately 200 species in 15 families. Almost all are from the fresh waters of North America. About 75% of the collection is from Illinois; the remainder is mostly from the southeastern United States. The best-represented groups are crayfishes, shrimps, scuds, slaters, and pill bugs.

A few specimens now housed in the collection were collected in the late 1800's by Stephen A. Forbes. They formed the basis for the first article to appear in the Survey's *Bulletin*: "List of Illinois Crustacea." Another large part of the collection was accumulated during the first half of the 1900's in conjunction with the insect surveys organized by Herbert H. Ross. However, most of the specimens were collected between 1972 and 1982 as part of the statewide survey that led to the publication in 1985 of "The Crayfishes and Shrimps (Decapoda) of Illinois" by Lawrence M. Page. The collection continues to grow at a rate of about 2,000–3,000 specimens a year.

The collection contains primary types of five species. About 90% of the collection, all except very old specimens needing reidentification, has been computerized. Lawrence M. Page is Curator and Kevin S. Cummings is Manager of the collection.

FISHES

Major components of the Fish Collection include specimens collected in Illinois from 1880 to 1905 for Stephen A. Forbes and Robert E. Richardson's "The Fishes of Illinois" published in 1908, and those collected from 1950 to 1978 for Philip W. Smith's "The Fishes of Illinois" published in 1979. More recent material is mainly from other areas of the United States and tropical America. Important recent acquisitions were a large part of Peter B. Bayley's collections of fishes from the Amazon River basin, Brazil, and the Fish Collection formerly housed at Southern Illinois University at Edwardsville. The geographic scope of the collection is about 50% from Illinois, 35% from elsewhere in North America, 10% from South Amerca, and 5% from elsewhere.

The collection contains approximately 650,000 specimens, which makes it the 15th or 16th largest collection of preserved fishes in North America. Represented are 115 families and 1,050 species. The value of the collection is greatly enhanced by the large number of historic specimens, many of which were collected in the 1800's from areas where they no longer occur. The collection contains primary types of 25 species and subspecies.

Computerization of the Fish Collection began in 1974 and is 90% completed. Information entered for each collection lot includes the catalog number, name of the species, number of specimens, the collection location (including distance from nearest town, county, state, and, when applicable, township, range, and section), date of collection, names of collectors, and a code number indicating the size of container in which a specimen is housed (to facilitate finding it when needed). A stream-drainage code, a system of coding the streams of Illinois in a hierarchical fashion, also is filed. The stream-drainage code is an 18-digit number that enables us to locate all the collections for a basin, drainage, or river system (e.g., Vermilion River system) as well as the locations originally filed (e.g., Vermilion River).

Growth of the Fish Collection varies greatly from year to year depending on the activities of the staff but in recent years has averaged about 30,000, or 5%, per year. Specimens are stored in 70% ethanol in glass jars with polypropylene lids. Most of the jars are housed in metal cabinets, protected from light and dust. About 200 specimens have been cleared and stained for study of bones and cartilage and are stored in glycerine. The Curator is Lawrence M. Page and Kevin S. Cummings is Manager of the collection.

AMPHIBIANS AND REPTILES

The Amphibian and Reptile Collection contains about 12,000 catalogued specimens representing approximately 550 species in 47 families and contains primary types of two species. Most of the specimens were collected in Illinois and the Midwest, but species from elsewhere in North America and Asia are represented. Most of the specimens were collected by Philip W. Smith during the completion of his comprehensive study, "The Amphibians and Reptiles of Illinois," published in 1961.

Presently there is no herpetologist on the staff, and growth of the collection has nearly stopped. Specimens are stored in metal cabinets in 70% ethanol in glass jars with polypropylene lids. The collection has been computerized. Lawrence M. Page and Kevin S. Cummings are the Curator and Manager, respectively, of the collection.

BIRDS

The Survey maintains a small (4,000 skins) collection of the birds of Illinois collected largely by Richard R. and Jean W. Graber and James W. Seets in the 1960's and 1970's. The collection includes several excellent series of birds that have declined within the State, especially the Loggerhead Shrike. The Bird Collection also has the world's largest collection (over 1,600 skins) of White-cheeked Geese assembled by Harold C. Hanson, who is preparing a monograph

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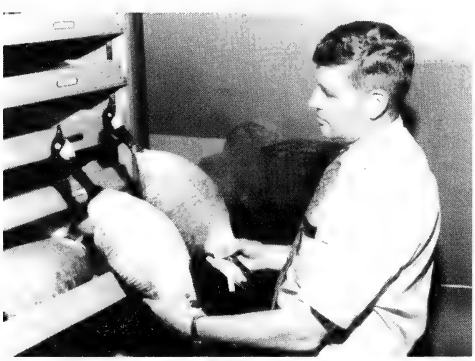
on the evolution and geographical races of the species. Additional holdings include over 500 egg sets, mostly from the Midwest, and several hundred nests. All skins are stored in cabinets. Curators of the collection are Harold C. Hanson and Scott K. Robinson.



Harold C. Hanson examining museum skins of White-cheeked Geese in his laboratory (photo by Les Woodrum).

MAMMALS

The Mammal Collection is essentially a synoptic collection of Illinois species. The 1,500 catalogued specimens (skins and skulls combined) of 91 species from 21 families are used as comparative material to identify specimens brought to the Survey. Most of the specimens were collected by Philip W. Smith between 1930 and 1950 in Illinois and surrounding states. The collection has been computerized. Lawrence M. Page is Curator and Kevin S. Cummings is Manager of the collection.

By *Lawrence M. Page, Director, Center for Biodiversity, in collaboration with the curators and managers of the various collections.*

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FEBRUARY 1990, NO. 294

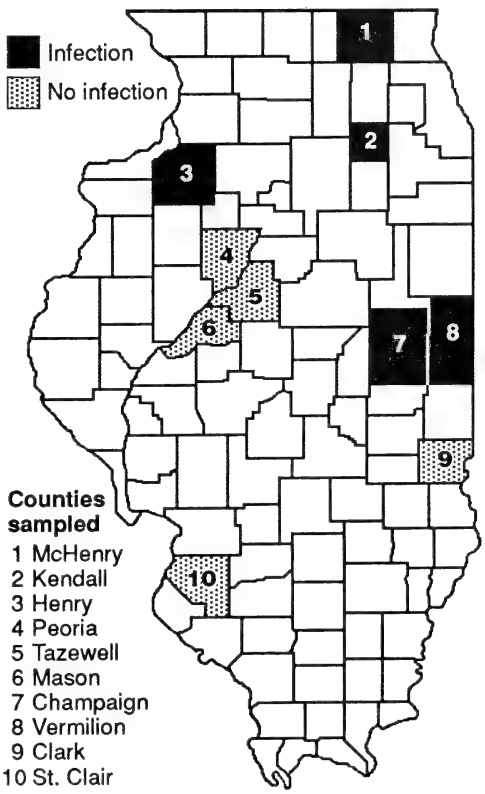
Potato Leafhopper Control

The potato leafhopper is one of the more important economic pests of alfalfa, potatoes, and snap beans in Illinois. *Zoophthora radicans* (Brefeld), a naturally occurring fungal pathogen of the potato leafhopper, has the potential to become a significant biological control agent of the leafhopper. *Z. radicans* was introduced into Illinois in 1984 from cultures obtained from infected leafhoppers collected in Wisconsin. These introductions are believed to be responsible for epizootics (increases in the number of infected leafhoppers) first observed in Illinois in 1985.

Asexual spores (conidia) of *Z. radicans* are forcefully discharged from infected leafhoppers. If they contact the body surface of a healthy leafhopper, they produce a germ tube that penetrates into the body cavity. The fungus continues to grow and spread throughout the body cavity until it kills the infected leafhopper in about three days. By the time the leafhopper dies, it is attached to the surface of the plant by small strands (hyphae) of the fungus that have grown out of the leafhopper's body. Other hyphae penetrate outward through the dead insect's body and form fruiting structures (conidiphores) from which the conidia are forcefully discharged. During periods of high humidity, many conidia are discharged and the disease spreads rapidly through a leafhopper population. A fungal epidemic results.

Some infected leafhoppers produce thick-walled (sexual) resting spores rather than asexual conidia. Several factors probably influence whether resting spores or conidia are formed. The thick-walled resting spores are much more resistant to unfavorable environmental conditions than are the conidia. The fungus overwinters as resting spores which germinate in the spring, infect leafhoppers, and repeat the cycle. *Z. radicans* has not reoccurred every year in every previously known location, an observation which suggests that such variables as drought, high temperatures, and other unfavorable environmental conditions affect the occurrence and spread of the fungus in leafhopper populations.

Survey entomologists are currently investigating the impact of *Z. radicans* on potato leafhopper populations in alfalfa in



Distribution of *Zoophthora radicans* in Illinois, 1985–1988.

order to incorporate this fungal pathogen into pest management systems. This fungus also shows promise as a biocontrol agent that can be introduced to induce outbreaks in populations of potato leafhoppers. Cooperative research with the USDA/ARS and Boyce Thompson Institute, Ithaca, New York, is focused on these field introductions and on the subsequent monitoring of the rate of spread of this insect pathogen both vertically and horizontally within the alfalfa canopy. Last summer two such introductions were successfully made on August 17 at locations near Bongard and Bondville in Champaign County, Illinois. Several weeks later, diseased potato leafhopper nymphs were reared from both sites. Additional fields, three near Bondville and four near Bongard, were sampled to eliminate the possibility that these disease outbreaks had occurred naturally. Infected nymphs were found in only one of those seven fields, a field one-quarter mile to the north of the Bongard release site. Infected adult potato leafhoppers may well have flown into this field from the release site and initiated a fungal outbreak.

This winter adult point-to-point transmission of *Z. radicans* will be studied under greenhouse conditions.

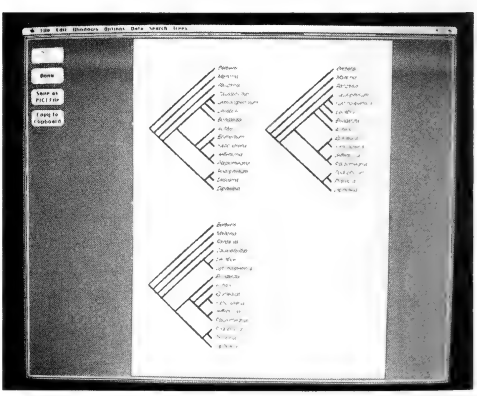
Stephen J. Roberts, Ann M. Kirts, Joseph V. Maddox, Cathy Hunter, and Edward J. Armbrust, Center for Economic Entomology.

Computer Software for Analyzing Evolutionary Relationships

The classification of biological organisms, known as *systematics*, has been a prominent component of research at the Survey since its inception in 1858. Systematists, in describing the patterns found in nature, lay the groundwork for many other areas of biology. The classifications they develop provide a common language that other biologists use daily. Not surprisingly, computers play an important role in systematic biology. A common application of computers in systematics is in the estimation of "evolutionary trees" (also called "phylogenies" or "cladograms"), branching diagrams that depict the way in which a set of contemporary species has evolved from a common ancestor. Many—probably most—systematists prefer to base classifications on inferred evolutionary relationships, although knowledge of these relationships can be quite useful in ways unrelated to classification.

One of the most widely used computer programs for inferring evolutionary trees is *PAUP* (Phylogenetic Analysis Using Parsimony), developed by David Swofford of the Survey's Center for Biodiversity. *PAUP* estimates evolutionary trees under the principle of maximum parsimony. This method searches for trees that provide the simplest explanation of the available data; i.e., trees that require the fewest assumptions of convergence (independent acquisitions of the same condition by unrelated species) and reversal (reversion from an advanced condition to one found in an earlier ancestor). Ironically, although the goal is simplicity, the problem tackled by *PAUP* belongs to a class of problems ("NP-complete") that are among the most difficult in computer science. *PAUP* uses sophisticated search algorithms (sequences of steps) that can quickly find exact solutions for small to medium-sized data sets. For larger data sets, *PAUP* uses approximate methods that do not guarantee optimal solutions but require much less computer time.

PAUP is being used by hundreds of biologists throughout the United States and Canada and on every major continent. Recently, a major revision, culminating in version 3.0, has greatly extended the program's capabilities and features. *PAUP* has grown from about 6,500 lines of Fortran (an older, somewhat cumbersome



A sample *PAUP* screen indicating three possible evolutionary trees for a family of plants.

language commonly used to write scientific application programs) to over 50,000 lines of C (a more modern language that overcomes many of Fortran's limitations). Significant enhancements were made in the treatment of molecular data (e.g., DNA and RNA sequences), and several new evolutionary models were incorporated. A complete reworking of the internal structure of the program yielded significant gains in performance, leading a reviewer in the British journal *Nature* to remark that *PAUP* 3.0 provides "an enormous increase in the accuracy and efficiency with which solutions can be obtained." The user interface was also redesigned, adding pulldown menus, dialog boxes, and a built-in editor to the old "command-line" interface. Computers supported include the IBM PC and compatibles and the Apple Macintosh. A fee of $50 serves to defray development and distribution expenses.

David Swofford, Center for Biodiversity

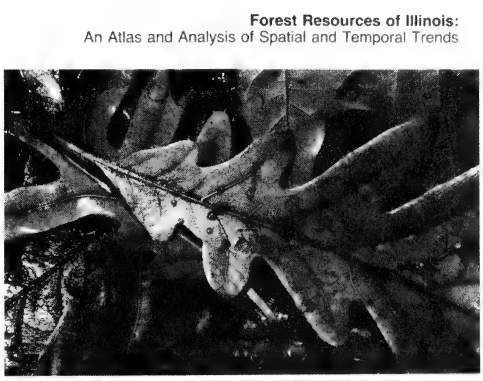
Forest Resources of Illinois

A recent Survey publication, *Forest Resources of Illinois: An Atlas and Analysis of Spatial and Temporal Trends*, brings together most of the information known about the current and historic condition of the state's forests. This 181-page book by the Forest Resource Analysis Committee of the Illinois Council on Forestry Development depicts forest trends over the past 170 years. Thirty-seven tables and more than 65 computer-generated maps, including a large wall map, make a wealth of detail at the county and regional level readily accessible to the reader. The appendices include an example of output from the Illinois Plant Information Network, a list of the 508 woody species of Illinois with their county distributions and natural community preferences, and a list of the 157 high-quality forested natural areas along with their locations and habitat types. A comprehensive bibliography of nearly 1,600 citations covers the research on or about Illinois forests since 1818.

Only a few highlights from this data-packed volume can be noted here.

In 1985, 4.26 million acres or 12% of Illinois was in forestland. Although this area represents only 31% of the forestland that existed at the time of European colonization, it does represent an increase of 10% over the acreage in 1962. The state now has 2.0 million acres of oak–hickory forests, 1.0 million acres of sugar maple forests, 0.7 million acres of elm–ash–soft maple forests, and lesser amounts of pine, oak–pine, and oak–gum–cypress forests. An estimated 1.9 billion live trees, including 186 million hickories, 203 million maples, 233 million oaks, and 343 million elms now occupy the commercial forests of Illinois. Much of the recent increase in forestland can be attributed to a reduction in the number of cattle with corresponding reductions in pasture and the effects of incentives to replace marginal cropland with forestland. The state has, however, seen dramatic changes in the composition of its forests since 1962: a loss of 14% of the oak–hickory, a loss of 53% of the elm–ash–soft maple, and a 4100% increase in sugar maple. This maple takeover is serious because oaks are not regenerating and the resulting maple forests are less valuable for wildlife habitat and timber resources.

Illinois ranks 32nd among the states in wood production (harvesting 161 million board feet of timber annually), yet it ranks fifth in wood consumption. Current net annual growth of Illinois forests exceeds



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430 million board feet, and total volume has increased 40% to 17.5 billion board feet since 1962. Thus, with environmental safeguards and proper management and marketing, the amount of wood harvested could be increased substantially without degrading the environment. Currently the forest industry employs about 55,000 workers and annually adds over $2 billion to the economy of the state.

Over 90% of the Illinois forestlands are privately owned, primarily by farmers and other individuals. Most of the public land (262,000 acres) is owned by the federal government as the Shawnee National Forest. Established fifty years ago, the Shawnee contributes much to the biodiversity of the state: 72 designated natural areas, 27% of the threatened or endangered plants in Illinois, 237 species of birds, 100 of amphibians and reptiles, and 109 of fish. It also contains a great deal of timber, the planned management of which is currently the subject of controversy.

Forestlands protect landscapes from wind and water erosion. Each year forestland erosion averages 1.6 tons per acre, but the average rate from Illinois cropland is 7 tons per acre per year. If the 1.75 million acres of the most erodible cropland in Illinois were converted to forests, overall annual erosion would be reduced by 37 million tons (current erosion exceeds 200 million tons). Windbreaks are also effective conservators. Estimates suggest that if the 124,000 rural heated buildings in Illinois were protected by windbreaks, heat energy savings would average 15%.

Forests provide extremely valuable habitat for the flora and fauna of the state; however, the forested landscape of Illinois is extremely fragmented, a condition that greatly reduces the biodiversity that it can support, especially with regard to birds of the forest interior. Nearly 50% (1,581 taxa) of the state's flora are associated with forests. In addition, 50% of the threatened and endangered species in Illinois are reported from and largely restricted to forestland. Only about 11,600 acres of relatively undisturbed forestland remain in Illinois, and the invasion of such exotic species as garlic mustard and honeysuckle pose a serious threat to the biodiversity of these remaining forests.

Finally, recreation in the Illinois outdoors is a $6.3 billion activity and much of it occurs on or near forestlands. Of particular significance are the urban forests because 83% of the state's population lives in urban areas. These forests have important aesthetic and psychological values, but they also have special problems, including disposing of cuttings and prunings, losses due to urban development, and management to accommodate large numbers of visitors.

A copy of this book and its accompanying wall map may be obtained for $4.00 by writing to the Survey.

Louis R. Iverson, Center for Biodiversity

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MARCH 1990, NO. 295

Estimating Fish Abundance

Information on the abundance of fish populations and/or community composition is vital for an understanding of the ecology and management of fisheries. A seine net of appropriate design is a simple, yet effective tool for sampling in waters where its passage is not impeded by unremovable snags. Although seine nets have been used since antiquity by fishermen and for more than 100 years for scientific and management purposes, researchers still do not know how representative the catch is compared to the actual numbers of fish in the environment. We are particularly concerned with variation due to fish size and species. For example, larger fish swim faster and are more able to escape a seine net before it is closed.

The seine net used in our research was 25 m long by 6 m deep with a 5-mm stretched mesh. It was laid from a boat in a circle 8 m in diameter and hauled by four persons. Capture efficiencies from field calibrations were compared to a series of microcomputer simulations to determine capture efficiency as a function of biologically realistic parameters. Efficiency can vary from 0% to 100%, depending on the size and species of fish and the mode of net operation. Physiologically and behaviorally realistic parameters of fish threatened with capture were incorporated into the simulation program. Visual effects were not considered because of the turbidity of the water; however, sound from the boat is known to cause fish to escape and its effect was simulated.

The following behavioral features were included: 1) swimming speed of the fish; 2) threshold distance, i.e., how close to the boat the fish must be before it initiates evasive action; 3) direction in which the fish swims; 4) "burst time," i.e., the time the fish swims without again sensing the boat; 5) the reaction of the fish when it encounters the partially closed net; 6) the ability of the fish to pass round, through, or under the closed net; 7) the effect of schooling, i.e., the tendency of some taxa to move in groups rather than independently. Values for item 1 are available for a wide variety of taxa. Regarding item 3, recent studies show that fish are able to identify the direction of a sound source and to react accordingly. Assumptions for item 5 depend on direct observations of fish in less turbid waters but were not critical factors in determining efficiencies. Item 6 was simulated on the basis of empirical data that indicated distinct escape characteristics for three groups of species. Simulations indicated that capture efficiency is largely controlled by items 1, 2, and 6.

Within realistic limits, computer simulations incorporated random variation of starting positions and specific behavioral

Simulation of the evasive behavior of individual fish as the net is set out counterclockwise from the 3 o'clock position. Fish have been positioned randomly at starting point 'S'. In (a) the fish has outrun the net and escaped; in (b) the net is about to close and the fish has not evaded capture.

features. Large numbers of fish were simulated as individuals. A trajectory for each fish was simulated until the fish was eventually captured or escaped. To make simulations more realistic, the direction and speed of individual fish were changed randomly between specified limits during successive stimulations as the net was laid. Using plausible ranges for fish speed, threshold distance, and other variables, we found that simulations matched observed mean capture efficiencies as a function of fish size and taxonomic group (e.g., 82% for 35-mm fish and 41% for 140-mm fish). The variability of simulated catchability also matched that of the empirical data.

Encouraged by the good fit of the simulation model to field results, we can now apply the principles of this approach to the use of seine nets in Illinois waters. Ultimately, we will be able to apply robust correction factors to field data, thereby generating unbiased abundance estimates that will allow fishery biologists to manage fish resources more effectively.

Peter B. Bayley and Robert A. Herendeen, Center for Aquatic Ecology

The Diamondback Moth: A Second Look at an Old Pest

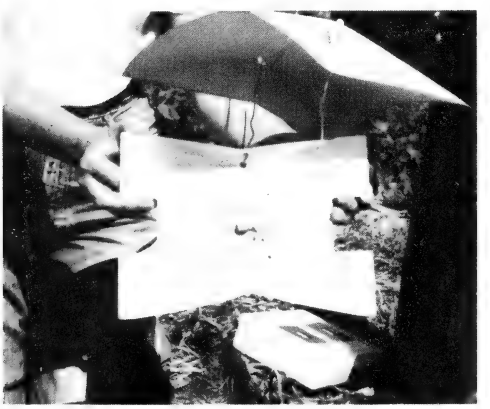
The diamondback moth (*Plutella xylostella*) is a pest of cruciferous crops, which include vegetables such as broccoli, cabbage, mustard greens, and horseradish as well as oilseeds such as canola (low-acid rapeseed). The larva or caterpillar feeds on leaves and reduces yield and quality through direct damage and as a contaminant in harvested produce. Thought to have originated in the Mediterranean region, the diamondback moth is now found from Iceland to the tropics but prefers temperate climates. Illinois has housed this unwelcome guest since about 1854, when the town of Ottawa provided the first report of its presence in the United States. In this country the diamondback moth has been viewed as a relatively minor pest because its capacity for damage was relatively small compared to that of major pests like the cabbage looper (*Trichoplusia ni*) and imported cabbageworm (*Artogeia rapae*). Since the mid-1980s, however, interest in the diamondback moth has grown dramatically because this insect has begun to show resistance to some insecticides in many parts of the country, including the Midwest.

Coinciding with this increased interest, Survey entomologists began studies on the field biology of the diamondback moth in southwestern Illinois as a continuation of research on insect pests of horseradish. Sweep net sampling, leaf examinations, and sex attractant traps were used to monitor diamondback development in several horseradish varieties in Madison and St. Clair counties during the 1988 and 1989 growing seasons. Observations and trap collections were also made in a canola field in Madison County from mid-March through harvest in early June 1989. Parasitoids were reared from diamondback eggs, larvae, and pupae taken from horseradish fields, and population data were collected on potential predators. Based on these studies, the diamondback moth appears to have six or more generations per year in southwestern Illinois depending on climatic conditions, especially temperature. One generation develops in early spring on wild hosts and overwintered crops such as canola and horseradish; another five or more are produced from late spring through early winter on long-season crops such as horseradish, which is planted in April and harvested partially in fall and the remainder the following spring. In August 1988, populations in some horseradish fields, particularly of the Commons variety, reached outbreak levels and required treatment. The greatly reduced rainfall that summer may have favored egg-laying and larval survival, which are adversely affected by heavy rains, and higher average temperatures may have speeded up larval development. In addition, increased use of insecticides to control invasions of false chinch bugs (*Nysius* spp.) may have reduced numbers of natural enemies that might normally have kept the diamondback moth under control. Diamondback populations in 1989, however, were very low throughout the season, perhaps as a result of regular heavy rains and less use of insecticides.

A laboratory colony established with insects from horseradish fields in 1988 was used to determine diamondback develop-

ment under controlled conditions and to evaluate the moth's preference for horseradish varieties. More eggs were laid on Commons than on Swiss and Eastern varieties—a finding that supports field observations; however, no consistent differences were found in larval development on these varieties. When reared on cabbage or horseradish at about 80°F, diamondback moths spent three days as eggs, seven to nine days as larvae, and three to four days as pupae. Adults could mate and lay eggs on the day of emergence from the pupal cocoon, but maximum egg-laying occurred four days later. Females have been reported to lay 100–300 eggs during their two- to three-week lifespan.

Because of concern over the possible development of resistance in Illinois populations of the diamondback moth, field trials and laboratory bioassays were undertaken in 1989. Formulations of five microbial insecticides (derived from *Bacillus thuringiensis*) were compared with a commonly used synthetic pyrethroid insecticide in cabbage plots in Champaign for seasonal control of diamondback moth, cabbage looper, and imported cabbageworm. Natural diamondback populations in the test plots were augmented with insects from the 1988 colony during the first part of the study. Although differences were found among insecticide products and formulations, all insecticides significantly reduced the numbers of caterpillars of the three species and the amount of damage to cabbage heads at harvest relative to numbers and damage in untreated plots.



Pheromone trap for monitoring male diamondback moths. Photo by H. Oloumi-Sadeghi.

However, in laboratory bioassays in which diamondback larvae from the 1988 colony were confined on insecticide-treated cabbage or horseradish foliage, the synthetic pyrethroid performed very poorly in comparison with the microbial insecticides. This insecticide was marginally effective against larvae when freshly applied to cabbage foliage but had no significant residual activity three days after treatment. When freshly applied to horseradish foliage, the synthetic pyrethroid was completely ineffective. These findings support the possibility that diamondback moths in Madison and St. Clair counties may be resistant to certain synthetic pyrethroids but indicate the need for further research with additional insecticides and in other crucifer-growing regions of the state. One region of concern is northern Illinois, where failures of certain insecticides to control diamondback larvae attacking cole crops were reported in 1987–1988.

These findings, aside from their importance to pest management in horseradish, are now serving as a foundation for a broader study on the status of the diamondback moth as a pest of cruciferous crops in Illinois. Of particular interest is the source of Illinois populations. Does this insect overwinter here? Does it fly into the state each year as a migrant or enter on infested crucifer seedlings brought in as spring transplants from the southern United States? All three possibilities may be taking place, and each will influence control strategies. Management of the diamondback moth must also be considered within the larger context of management of the complex of insects, particularly other caterpillar species, that routinely affect production of cruciferous crops in Illinois. Research designed to provide a clearer picture of factors influencing diamondback populations in this state is being expanded so that economic thresholds and appropriate management practices can be developed to halt the potential shift of the diamondback moth from minor to major pest status.

Catherine Eastman and Hassan Oloumi-Sadeghi, Center for Economic Entomology

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Darter Life Histories

As concern for protecting rare species and other components of our native biota has risen, so has the need for more information on ecological requirements. One area related to this need in which the Illinois Natural History Survey has a national reputation is the study of the life histories of fishes. These studies typically include a two- or three-year period of field work along with laboratory observations on reproduction. Principal subjects studied include habitat requirements, food habits, spawning habits, and demographic characteristics of the species.

Two closely related fishes, the bandfin darter (*Etheostoma zonistium*) and the firebelly darter (*E. pyrrhogaster*) are the subjects of the most recent life history study. The data collected indicated that both species prefer stream margins near emergent vegetation or exposed tree roots. They live a maximum of three years and reach sexual maturity at one year. From March to June they lay eggs that are about 1.1 mm in diameter. During the spawning period, males of both species are brilliantly colored. Newly hatched larvae are about 4 mm long. Males reach a maximum total length of about 60 mm, females about 55 mm. Principal food items of both species are microcrustaceans and aquatic insect larvae. "Life Histories of the Bandfin Darter, *Etheostoma zonistium*, and the Firebelly darter, *Etheostoma pyrrhogaster*, in Western Kentucky" by Douglas A. Carney and Brooks M. Burr is available for $2.00 by writing to the Natural History Survey and requesting *Biological Notes 134*.

Larry M. Page, Center for Biodiversity

Life Histories of the Bandfin Darter, *Etheostoma zonistium*, and the Firebelly Darter, *Etheostoma pyrrhogaster*, in Western Kentucky

Douglas A. Carney
Brooks M. Burr

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The Illinois
NATURAL HISTORY
SURVEY REPORTS

APRIL 1990, NO. 296

Effects of Forest Fragmentation on Nesting Songbirds

As the forests of Illinois have been cut and replaced by agriculture and suburbs, the remaining tracts have become smaller, more isolated, and increasingly dominated by "edge" habitats. This process of forest fragmentation is now known to have an adverse effect on many kinds of wildlife, especially nongame species. Populations of many forest species have been declining throughout the East, and many characteristic forest species do not occur in woodlots below a certain minimum size. Small, edge-dominated woodlots contain abnormally high populations of brood parasitic brown-headed cowbirds and such nest predators as blue jays, raccoons, and opossums, all of which feed both in the forest and in surrounding agricultural fields or suburban yards. Brown-headed cowbirds pose a particularly severe problem because they lay their eggs in the nests of other species. The host raises the cowbird as if it were its own young, and parasitized nests seldom fledge host young. As a result of the combined effects of cowbirds and nest predators, ecologists have begun to question whether populations of most forest birds of Illinois are producing enough young to replace themselves.

Evidence for a worst-case scenario comes from a study in the highly fragmented Lake Shelbyville area of central Illinois. In three small (35 to 170 acres), edge-dominated woodlots, I found little evidence of successful reproduction of forest birds that winter in the tropics but breed in Illinois (neotropical migrants). Most nests found in the area failed because of high predation rates (80% of all nests) and brood parasitism by cowbirds (76% of the nests of neotropical migrants). Parasitized nests with more than one cowbird egg were the rule rather than the exception, with an average of 3.3 cowbird eggs per parasitized nest. Wood thrush nests averaged nearly four times as many cowbird as thrush eggs; one nest contained 12 cowbird and no host eggs. These are the highest predation and parasitism rates ever recorded for a forest bird community. Only 10% of the birds captured in nets late in the summer were juveniles, an extremely low ratio. Taken together, these data strongly suggest that populations of most neotropical migrants do not produce enough young to replace themselves in the Shelbyville area. Populations of most of these species are probably maintained by immigrants from larger forests elsewhere in the Midwest. Given this low reproductive success, we should not be surprised that Shelbyville populations of seven species of neotropical migrants have declined by at least 50% in the last 5 years. Although we do not as yet know if these declines represent long-term population losses or short-term fluctuations, the trends merit concern.

Do birds nesting in larger tracts of forest face the same problems as those nesting in small agricultural woodlots? To answer this question, I began a study of the effects of habitat fragmentation on forest birds in the 260,000-acre Shawnee National Forest of extreme southern Illinois. This research was funded primarily by the Illinois Department of Energy and Natural Resources, with additional funds from the U.S. Forest Service, the Illinois Department of Conservation, and the U.S. Fish and Wildlife Service. A crew of 14 searched for and monitored nests, censused bird

populations, and caught and marked key neotropical migrant species. Our purpose was to determine how far into the forest high rates of cowbird parasitism and nest predation extended.

Preliminary results show that cowbird parasitism is a far more serious problem than we anticipated, even deep in the forest interior. Cowbirds were found throughout study areas regardless of the proximity of edges, a result that differs from studies elsewhere in the Midwest. Roughly 55% of the 450 nests found in 1989 contained at least one cowbird egg. The wood thrush was hardest hit: over 90% of 92 nests were parasitized with an average of more than three cowbird eggs per nest. Wood thrushes nesting far (over 400 m) from edges were just as heavily parasitized as those nesting closer to edges. If these data are combined with those from the Shelbyville area, a gloomy picture of the wood thrush's future in Illinois emerges. Other species that appear to suffer heavily from cowbird parasitism include the hooded warbler, Louisiana waterthrush, red-eyed vireo, and scarlet and summer tanagers.

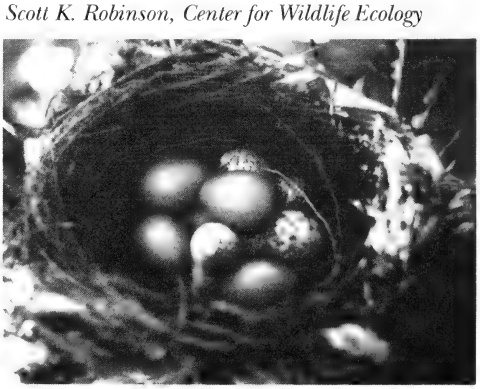
The situation may not be as grim for some other species. Worm-eating warblers, for example, had a successful nesting season in 1989, especially in the largest, most undisturbed tracts. Kentucky warblers appear to tolerate limited disturbances well and only about 40% of their nests were parasitized by cowbirds. Parasitism rates of Acadian flycatchers varied among study areas from a low of 20% to a high of 65%. Some local populations of Acadian flycatchers may therefore be self-sustaining or even produce a surplus of young to recolonize less successful populations. Some species that strongly prefer nesting on the forest edge (e.g., white-eyed vireo, indigo bunting) also proved more resistant to cowbird parasitism. Clearly, future management decisions will have to take into account differences in vulnerability among species.

Nest predation appears to be somewhat less of a problem in the Shawnee than in the Shelbyville area. Overall rates for each forest species ranged from 50 to 80%. At least one species, the Acadian flycatcher, had higher rates near the edges of clearcuts, wildlife openings, and agricultural fields. These results conform with those from studies elsewhere in the Midwest and East that also show high predation rates along edges. Management strategies to minimize edge within large tracts may therefore reduce predation rates for some species.

Although management practices cannot be based on these early results, several lessons have emerged. First, we must look at each forest species separately when designing management schemes. Second, the cowbird problem is more serious than anticipated and cannot be solved simply by minimizing edges as has been proposed elsewhere in the Midwest. Third, at least some species nest most successfully in large undisturbed tracts, whereas others may do as well (or as poorly) in disturbed and undisturbed tracts. And fourth, some species, such as the wood thrush, may be in serious trouble throughout the Midwest and merit special attention. The reproductive success of birds in the Shawnee Forest is not as low as it is in the very fragmented Shelbyville area, but populations of many species may not be producing enough young to replace themselves at either site.

Scott K. Robinson, Center for Wildlife Ecology

The wood thrush (*Hylocichla mustelina*) is the most heavily parasitized forest bird in Illinois. Photo by Jean W. Graber.



A wood thrust nest with six cowbird (speckled) and five host eggs. Photo taken in the Shawnee National Forest by Scott K. Robinson.

Compactors for INHS Insect Collection

The official insect collection of the state of Illinois is housed at the Natural History Survey. Its 6,000,000 specimens document our knowledge of the insects of the state, including distribution, behavior, life history, and pest status. This collection, the sixth largest in North America, represents more than a century of effort by those who seek to understand and appreciate the insect fauna of Illinois.

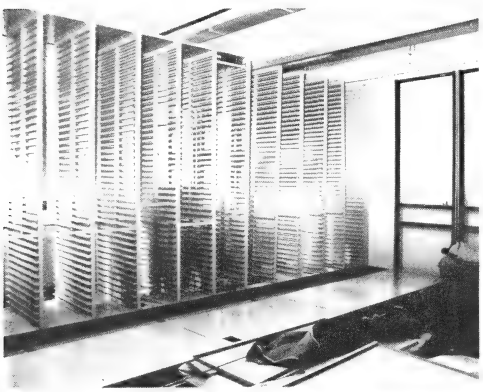
The need for additional space in which to store this irreplaceable resource became apparent in the late 1960s. A few years later, compactors became available, and Survey scientists sought funds to install such a space-saving system. In 1979, a request was made for Capitol Development Funds. After several years of negotiation, money became available in 1987.

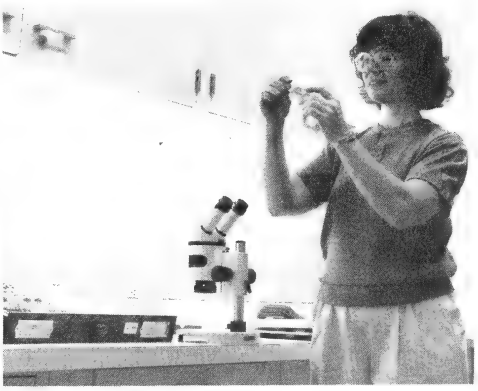
In the interim, the National Science Foundation was approached for funds to support the transfer of specimens to the new storage system and other collection-related needs. This request was approved, and a continuation grant was made for 1989 and 1990.

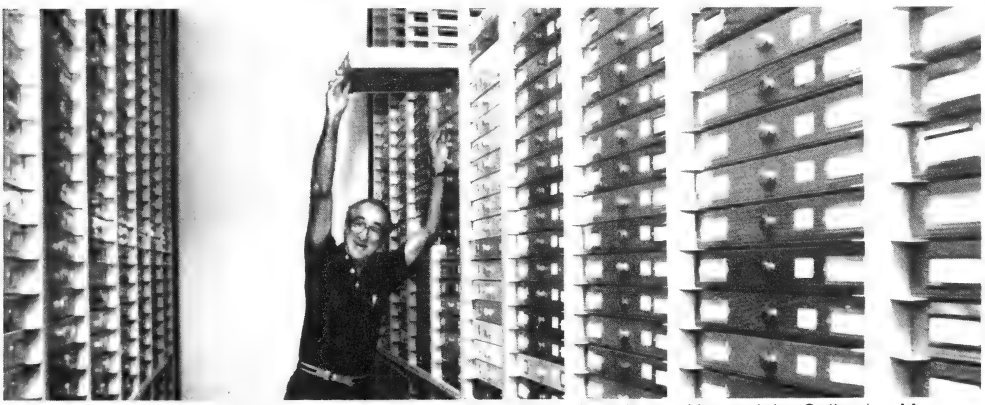
Construction of the storage system began in December of 1988 and was completed in August of 1989. The compactor consists of seven mobile and two stationary storage units. Two aisles can be opened at desired locations by electronically moving the units. The system holds nearly 8,000 insect drawers and the equivalent of 24 cabinets of specimens stored in alcohol.

Prior to installation, the room that was to house the collection was remodeled. The new facility includes not only the compactor but a visitor's work station, two offices for staff, and a preparation, packing, and storage area. The compactor holds the Survey's entire collection of pinned insects, a third of its specimens stored in alcohol, and enough new drawers to nearly double the capacity for pinned specimens. The new system should provide space for expansion for the next two decades.

Wallace E. LaBerge and Kathryn C. McGiffen, Center for Biodiversity







Upper left. The shelving supports are positioned on motorized carriages. Upper right. Collection Manager Kathryn C. McGiffen examines an insect specimen at the work station. Lower. With the installation complete, Wallace E. LaBerge, Curator of Bees and Ants, organizes the insect drawers.

The Illinois
NATURAL HISTORY SURVEY
NATURAL RESOURCES BUILDING
607 EAST PEABODY DRIVE
CHAMPAIGN, ILLINOIS 61820

Update: Deer Tick and Lyme Disease

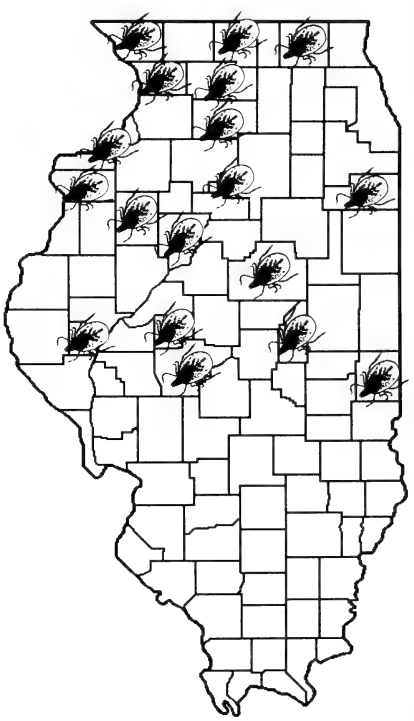
With warm weather approaching, readers of *Survey Reports* are reminded that the deer tick and Lyme disease are present in Illinois. According to information recently released by the Illinois Department of Public Health, 79 cases of Lyme disease were reported from Illinois during 1989. Thirty-nine of the patients reported their most likely exposure to have been in Illinois, and 69 of the cases were from the northern two-thirds of the state.

As would be expected, the distribution of cases of Lyme disease in Illinois corresponds well with the known distribution of the deer tick, the vector of the causative agent of Lyme disease, the spirochete *Borrelia burgdorferi*. The deer tick has now been detected in 18 counties in the state, all of them north of the 39° parallel. During 1989, the deer tick was detected for the first time in Winnebago, McHenry, Peoria, McLean, Menard, Sangamon, and Brown counties. The deer tick is particularly prevalent in some counties along the Rock River in northwestern Illinois.

Persons engaged in outdoor work and recreation in Illinois are again advised to take suitable precautions against tick bite. In a tick-infested area, the best protection is to wear sturdy shoes, long pants with cuffs tucked into socks, and long-sleeved shirts with cuffs. Additional protection can be obtained by applying tick-repelling sprays to clothing, not to the skin.

Persons who wish to submit ticks for identification should send them in alcohol to John K. Bouseman at the Survey's Center for Economic Entomology.

John K. Bouseman, Center for Economic Entomology, and Dr. Uriel D. Kitron, College of Veterinary Medicine. Dr. Kitron is also an affiliate of the Center for Economic Entomology.



Known distribution in Illinois by county of the deer tick, *Ixodes dammini*.

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For additional copies of this publication or for a catalog of Survey publications, write to DR. LORIN I. NEVLING, CHIEF, ILLINOIS NATURAL HISTORY SURVEY, NATURAL RESOURCES BUILDING, 607 EAST PEABODY DRIVE, CHAMPAIGN, ILLINOIS 61820.

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